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WO 02/057222 A2

(54) Title: THIOL-BASED NAALADASE INHIBITORS

(57) Abstract: This invention relates to new compounds, pharmaceutical compositions and diagnostic kits comprising such compounds, and methods of using such compounds for inhibiting NAALADase enzyme activity, detecting diseases where NAALADase levels are altered, effecting neuronal activity, effecting TGF- β activity, inhibiting angiogenesis, and treating glutamate abnormalities, diabetic neuropathy, pain, compulsive disorders, prostate diseases, cancers and glaucoma.

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WO 02/057222

PCT/US02/01205

THIOL-BASED NAALADASE INHIBITORS

This application claims the benefit of U.S. Provisional Application No. 60/261,754, filed January 17, 2001, and U.S. Provisional Application No. 60/342,772, filed December 28, 5 2001, the entire contents of which applications are herein incorporated by reference.

This invention relates to new compounds, pharmaceutical compositions and diagnostic kits comprising such compounds, and methods of using such compounds for inhibiting NAALADase 10 enzyme activity, detecting diseases where NAALADase levels are altered, effecting neuronal activity, effecting TGF- β activity, inhibiting angiogenesis, and treating glutamate abnormalities, diabetic neuropathy, pain, compulsive disorders, prostate diseases, cancers and glaucoma.

15 The NAALADase enzyme, also known as prostate specific membrane antigen ("PSM" or "PSMA") and human glutamate carboxypeptidase II ("GCP II"), catalyzes the hydrolysis of the neuropeptide N-acetyl-aspartyl-glutamate ("NAAG") to N-acetyl-aspartate ("NAA") and glutamate. Based upon amino 20 acid sequence homology, NAALADase has been assigned to the M28 family of peptidases.

Studies suggest NAALADase inhibitors may be effective in treating ischemia, spinal cord injury, demyelinating diseases, Parkinson's disease, Amyotrophic Lateral Sclerosis 25 ("ALS"), alcohol dependence, nicotine dependence, cocaine

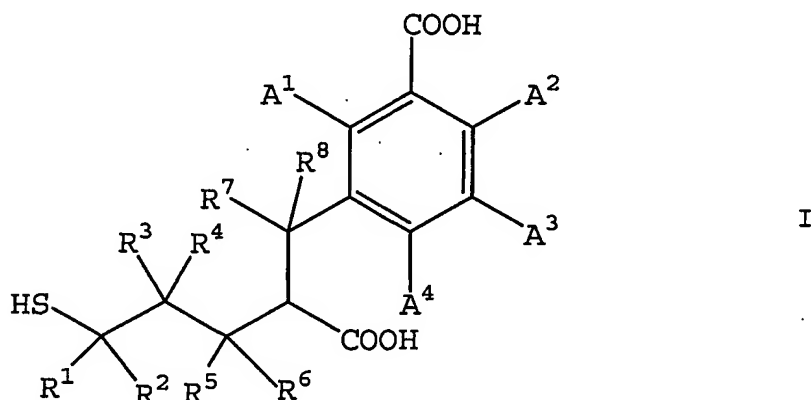
WO 02/057222

PCT/US02/01205

dependence, cancer, diabetic neuropathy, pain and schizophrenia, and in inhibiting angiogenesis. In view of their broad range of potential applications, a need exists for new NAALADase inhibitors and pharmaceutical compositions comprising such compounds.

SUMMARY OF THE INVENTION

This invention relates to a compound of formula I



or a pharmaceutically acceptable equivalent of said compound, wherein:

R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 and R^8 are independently hydrogen or C_1 - C_3 alkyl;

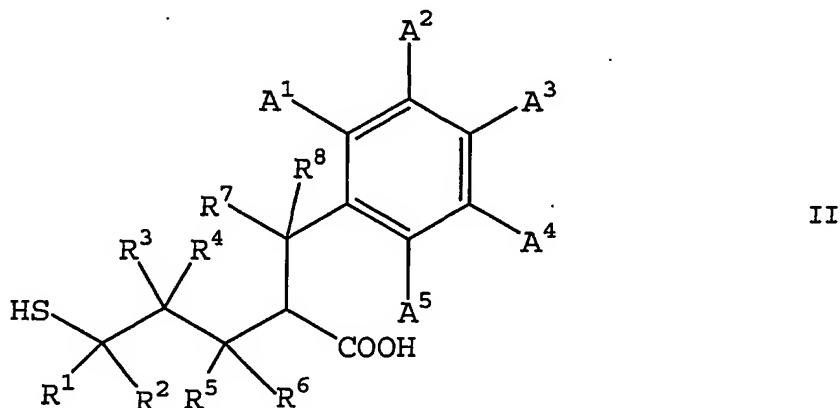
A^1 , A^2 , A^3 and A^4 are independently hydrogen, C_1 - C_6 alkyl, C_1 - C_6 alkoxy, halo, nitro, phenyl, phenoxy, benzyl, benzyloxy or $-COOH$, or any adjacent two of A^2 , A^3 and A^4 form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring

WO 02/057222

PCT/US02/01205

containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s).

This invention further relates to a compound of formula II



5

or a pharmaceutically acceptable equivalent of said compound, wherein:

R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 and R^8 are independently hydrogen or C_1 - C_3 alkyl; and

10 A^1 , A^2 , A^3 , A^4 and A^5 are independently hydrogen, C_1 - C_6 alkyl, C_1 - C_6 alkoxy, C_1 - C_3 perhaloalkyl, phenyl, phenoxy, benzyl, benzyloxy, hydroxy, halo, cyano, nitro, $-SO_2R^9$, $-(C=O)NR^9R^{10}$, $-(C=O)NR^9(CH_2)_nCOOH$, $-NR^9(C=O)R^{10}$, $-(CH_2)_nCOOH$ or $-COOH$, or any adjacent two of A^1 , A^2 , A^3 , A^4 and A^5 form with
 15 the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s);

WO 02/057222

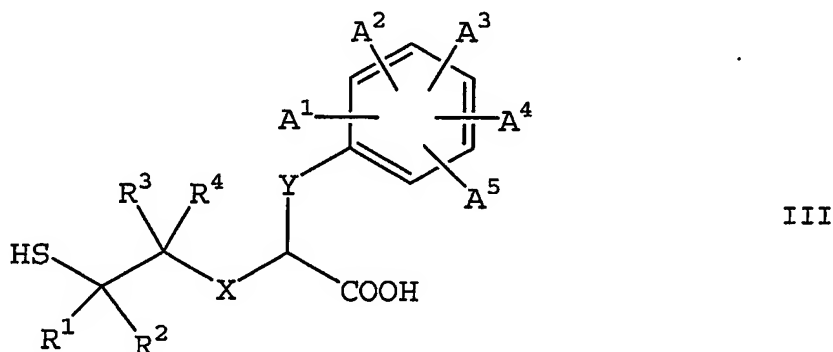
PCT/US02/01205

R^9 and R^{10} are independently hydrogen, C_1 - C_6 alkyl, phenyl or benzyl; and

n is 1-3;

provided that if A^1 , A^3 and A^5 are independently
 5 hydrogen, C_1 - C_6 alkyl, C_1 - C_6 alkoxy, halo, nitro, phenyl, phenoxy, benzyl, benzyloxy or $-COOH$, then neither A^2 nor A^4 are $-COOH$; and provided that if any adjacent two of A^3 , A^4 and A^5 form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic
 10 aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s), then A^2 is not $-COOH$.

This invention also relates to a compound of formula
 III



15 or a pharmaceutically acceptable equivalent of said compound, wherein:

X and Y are independently $-CR^5R^6-$, $-O-$, $-S-$ or $-NR-$, provided that at least one of X and Y is/are $-CR^5R^6-$;

WO 02/057222

PCT/US02/01205

A¹, A², A³, A⁴ and A⁵ are independently hydrogen, C₁-C₉, alkyl, C₂-C₉ alkenyl, C₂-C₉ alkynyl, aryl, heteroaryl, carbocycle, heterocycle, C₁-C₉ alkoxy, C₂-C₉ alkenyloxy, phenoxy, benzyloxy, hydroxy, halo, nitro, cyano, isocyano,
5 -COOR⁷, -COR⁷, -NR⁷R⁸, -SR⁷, -SOR⁷, -SO₂R⁷, -SO₂(OR⁷),
- (C=O)NR⁷R⁸, - (C=O)NR⁷(CH₂)_nCOOH, -NR⁷(C=O)R⁸ or -(CH₂)_nCOOH, or
any adjacent two of A¹, A², A³, A⁴ and A⁵ form with the benzene
ring a fused ring that is saturated or unsaturated, aromatic
or non-aromatic, and carbocyclic or heterocyclic, said
10 heterocyclic ring containing 1 or 2 oxygen, nitrogen and/or
sulfur heteroatom(s);

n is 1-3;

R, R¹, R², R³, R⁴, R⁵, R⁶, R⁷ and R⁸ are independently
hydrogen, C₁-C₉ alkyl, C₂-C₉ alkenyl, C₂-C₉ alkynyl, aryl,
15 heteroaryl, carbocycle or heterocycle; and

said alkyl, alkenyl, alkynyl, aryl, heteroaryl,
carbocycle, heterocycle, alkoxy, alkenyloxy, phenoxy,
benzyloxy, and fused ring are independently unsubstituted or
substituted with one or more substituent(s);

20 provided that if A¹, A² and A³ are each hydrogen, and A⁴
and A⁵ are each -COOH, then A⁴ is *ortho* to A⁵; and provided
that if Y is -CR⁵R⁶-, then at least one of A¹, A², A³, A⁴ and
A⁵ is/are independently phenoxy, benzyloxy, aryl, heteroaryl,
carbocycle or heterocycle that is substituted with one or
25 more substituent(s).

WO 02/057222

PCT/US02/01205

Additionally, this invention relates to method for inhibiting NAALADase enzyme activity, treating a glutamate abnormality, effecting a neuronal activity, treating a prostate disease, treating cancer, inhibiting angiogenesis or
5 effecting a TGF- β activity, comprising administering to a mammal in need of such inhibition, treatment or effect, an effective amount of a compound of formula I, II or III, as described above.

This invention further relates to method for detecting a
10 disease, disorder or condition where NAALADase levels are altered, comprising:

(i) contacting a sample of bodily tissue or fluid with a compound of formula I, II or III, as defined above, wherein said compound binds to any NAALADase in said sample;
15 and

(ii) measuring the amount of any NAALADase bound to said sample, wherein the amount of NAALADase is diagnostic for said disease, disorder or condition.

This invention also relates to a method for detecting a
20 disease, disorder or condition where NAALADase levels are altered in an animal or a mammal, comprising:

(i) labeling a compound of formula I, II or III, as defined above, with an imaging reagent;

(ii) administering to said animal or mammal an
25 effective amount of the labeled compound;

WO 02/057222

PCT/US02/01205

(iii) allowing said labeled compound to localize and bind to NAALADase present in said animal or mammal; and

(iv) measuring the amount of NAALADase bound to said labeled compound, wherein the amount of NAALADase is
5 diagnostic for said disease, disorder or condition.

Additionally, this invention further relates to a diagnostic kit for detecting a disease, disorder or condition where NAALADase levels are altered, comprising a compound of formula I, II or III, as defined above, labeled
10 with a marker.

Finally, this invention relates to a pharmaceutical composition comprising:

- (i) an effective amount of a compound of formula I, II or III, as described above; and
15 (ii) a pharmaceutically acceptable carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a bar graph showing the effect of 2-(phosphonomethyl)pentanedioic acid ("Compound C") on TGF- β 1
20 concentrations in ischemic cell cultures.

FIG. 2 is a bar graph showing the effect of Compound C on TGF- β 2 concentrations in ischemic cell cultures.

WO 02/057222

PCT/US02/01205

FIG. 3 is a bar graph showing the reversal of the neuroprotective effect of Compound C by TGF- β neutralizing antibodies in ischemic cell cultures.

FIG. 4 is a bar graph showing the non-reversal of the neuroprotective effect of Compound C by FGF neutralizing antibodies in ischemic cell cultures.

FIG. 5 is a bar graph showing the reversal of the neuroprotective effect of Compound C by TGF- β neutralizing antibodies in rats subjected to middle cerebral artery occlusion ("MCAO").

FIG. 6 is a bar graph showing the effect of Compound C on TGF- β 1 levels during occlusion and reperfusion in rats subjected to MCAO.

FIG. 7A is a bar graph plotting the withdrawal latency difference scores of non-diabetic rats and STZ-diabetic rats treated with a vehicle or 2-[[2,3,4,5,6-pentafluorobenzyl)hydroxyphosphinyl)methyl]pentanedioic acid ("Compound A"), against the days following administration with streptozotocin ("STZ").

FIG. 7B is a bar graph plotting the withdrawal latency difference scores of non-diabetic rats and STZ-diabetic rats treated with a vehicle or 2-(2-sulfanylethyl)pentanedioic acid ("Compound D"), against the days following administration with STZ.

WO 02/057222

PCT/US02/01205

FIG. 8 is a bar graph plotting the withdrawal latency difference scores of normal (unoperated) rats and chronic constrictive injury-induced rats treated with a vehicle or Compound C, against the days following surgery.

5 FIG. 9A is a bar graph plotting the motor nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated with a vehicle or Compound A, against the weeks post STZ.

10 FIG. 9B is a bar graph plotting the sensory nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated with a vehicle or Compound A, against the weeks post STZ.

15 FIG. 10A is a bar graph plotting the motor nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated with a vehicle or Compound D, against the weeks post STZ.

20 FIG. 10B is a bar graph plotting the sensory nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated with a vehicle or Compound D, against the weeks post STZ.

FIG. 11 is a graph plotting the withdrawal latency of non-diabetic rats and BB/W diabetic rats treated with a vehicle, Compound D or Compound A, against the weeks of treatment.

WO 02/057222

PCT/US02/01205

FIG. 12 is a graph plotting the nerve conduction velocity of non-diabetic rats and BB/W diabetic rats treated with a vehicle, Compound D or Compound A, against the weeks of treatment.

5 FIG. 13 is a bar graph plotting the withdrawal latency differences in scores of chronic constrictive injury-induced rats treated with a vehicle or 10 mg/kg 3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid ("Compound 49"), against the days following treatment.

10 FIG. 14 is a bar graph plotting the withdrawal latency differences in scores of chronic constrictive injury-induced rats treated with a vehicle or 1 mg/kg Compound 49, against the days following treatment.

15 FIG. 15 is a bar graph plotting the withdrawal latency differences in scores of chronic constrictive injury-induced rats treated with a vehicle or 0.1 mg/kg Compound 49, against the days following treatment.

20 FIG. 16 is a bar graph plotting the withdrawal latency of chronic constrictive injury-induced rats treated with a vehicle or 10, 1 or 0.1 mg/kg Compound 49, against the days following treatment.

FIG. 17 is a bar graph plotting the withdrawal latency differences in scores of chronic constrictive injury-induced rats treated with a vehicle or 50 mg/kg 3-carboxy-alpha-(3-

WO 02/057222

PCT/US02/01205

mercaptopropyl)-benzenepropanoic acid ("Compound 5"),
against the days following treatment.

FIG. 18 is a bar graph plotting the withdrawal latency
differences in scores of chronic constrictive injury-induced
5 rats treated with a vehicle or 30 mg/kg Compound 5, against
the days following treatment.

FIG. 19 is a bar graph plotting the withdrawal latency
differences in scores of chronic constrictive injury-induced
rats treated with a vehicle or 10 mg/kg Compound 5, against
10 the days following treatment.

FIG. 20 is a bar graph plotting the withdrawal latency
differences in scores of chronic constrictive injury-induced
rats treated with a vehicle or 3 mg/kg Compound 5, against
the days following treatment.

15 FIG. 21 is a bar graph plotting the withdrawal latency
differences in scores of chronic constrictive injury-induced
rats treated with a vehicle or 1 mg/kg Compound 5, against
the days following treatment.

FIG. 22 is a bar graph plotting the withdrawal latency
20 differences in scores of chronic constrictive injury-induced
rats treated with a vehicle or 0.3 mg/kg Compound 5, against
the days following treatment.

FIG. 23 is a bar graph plotting the withdrawal latency
of chronic constrictive injury-induced rats treated with a

WO 02/057222

PCT/US02/01205

vehicle or 10, 30 or 50 mg/kg Compound 5, against the days following treatment.

FIG. 24 is a bar graph plotting the percent of transgenic mice at 210 days of age that exhibited limb shaking after treatment with 2-(3-sulfanypropyl)pentanedioic acid ("Compound B") or a vehicle.

FIG. 25 is a bar graph plotting the gait, measured on an arbitrary scale ranging from 0 to 3, of transgenic mice at 210 days of age after treatment with Compound B or a vehicle.

FIG. 26 is a bar graph plotting hind limbs dragging, measured on an arbitrary scale ranging from 0 to 3, of transgenic mice at 210 days of age after treatment with Compound B or a vehicle.

FIG. 27 is a bar graph plotting the crossing of limbs, measured on an arbitrary scale ranging from 0 to 3, of transgenic mice at 210 days of age after treatment with Compound B or a vehicle.

FIG. 28 is a bar graph plotting the righting reflex of transgenic mice, measured by the time (seconds) it took the mice to right themselves when placed on their sides, at 210 days of age after treatment with Compound B or a vehicle.

WO 02/057222

PCT/US02/01205

FIG. 29 is a graph plotting the percent of transgenic mice treated with Compound B or a vehicle that died against the age of the mice (days).

FIG. 30 is a Kaplan-Meier survival graph plotting
5 the percent of transgenic mice treated with Compound B or a vehicle that survived against the number of days that the mice were on study therapy.

FIG. 31 is a bar graph plotting the withdrawal latency difference scores of non-diabetic rats and STZ-diabetic rats
10 treated with a vehicle, Compound D or 3-carboxy-alpha-(3-mercaptopropyl)benzenepropanoic acid ("Compound E"), against the weeks of treatment.

FIG. 32 is a bar graph plotting motor nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated
15 with a vehicle, Compound D or Compound E, against the weeks of treatment.

FIG. 33 is a bar graph plotting sensory nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated with a vehicle, Compound D or Compound E,
20 against the weeks of treatment, where treatment started 5 weeks post STZ.

FIG 34 is a bar graph plotting the withdrawal latency difference scores of non-diabetic rats and STZ-diabetic rats treated with a vehicle or lower doses of Compound D (1 and 3,

WO 02/057222

PCT/US02/01205

mg/kg), against the weeks of treatment, where treatment started 7 weeks post STZ.

FIG. 35 is a bar graph plotting motor nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated
5 with a vehicle or lower doses of Compound D (1 and 3 mg/kg), against the weeks of treatment, where treatment started 7 weeks post STZ.

FIG. 36 is a bar graph plotting sensory nerve conduction velocity of non-diabetic rats and STZ-diabetic
10 rats treated with a vehicle or lower doses of Compound D (1 and 3 mg/kg), against the weeks of treatment, where treatment started 7 weeks post STZ.

FIG. 37 are bar graphs plotting sensory nerve conduction velocity of non-diabetic rats and STZ-diabetic
15 rats treated with a vehicle or Compound D at 35 days and 60 days after treatment, where treatment started 60 days post STZ.

FIG. 38 are bar graphs plotting motor nerve conduction velocity of non-diabetic rats and STZ-diabetic rats treated
20 with a vehicle or Compound D at 35 days after treatment, where treatment started 60 days post STZ.

FIG. 39 is a graph plotting sensory nerve conduction velocity of non-diabetic and STZ-diabetic rats treated with
a vehicle or Compound D, against the days post STZ, where
25 treatment started 90 days post STZ.

WO 02/057222

PCT/US02/01205

FIG. 40 is a bar graph plotting motor and sensory nerve conduction velocities of non-diabetic mice and db/db diabetic mice before treatment with a NAALADase inhibitor.

FIG. 41 is a bar graph plotting motor and sensory nerve
5 conduction velocities of non-diabetic mice and db/db diabetic mice after treatment with 3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)benzenepropanoic acid ("Compound F").

FIG. 42 is bar graph comparing the rotarod
10 performance of transgenic HD mice and normal non-HD mice treated with Compound B, and transgenic HD mice and normal non-HD mice treated with a vehicle.

FIG. 43 is a bar graph comparing the total distance
15 traveled by transgenic HD mice and normal non-HD mice treated with Compound B, and transgenic HD mice and normal non-HD mice treated with a vehicle.

FIG. 44 is a graph plotting the survival time of transgenic D mice treated with Compound B or a vehicle.

FIG. 45 is a graph plotting the survival time of
20 male transgenic HD mice treated with Compound B or a vehicle.

FIG. 46 is a graph plotting the survival time of female transgenic HD mice treated with Compound B or a vehicle.

WO 02/057222

PCT/US02/01205

DETAILED DESCRIPTION

DEFINITIONS

"Compound A" refers to 2-[[2,3,4,5,6-pentafluorobenzyl)hydroxyphosphinyl)methyl]pentanedioic
5 acid.

"Compound B" refers to 2-(3-sulfanylpropyl)pentanedioic acid.

"Compound C" refers to 2-(phosphonomethyl)pentanedioic acid (PMPA).

10 "Compound D" refers to 2-(2-sulfanylethyl)pentanedioic acid.

"Compound E" refers to 3-carboxy-alpha-(3-mercaptopropyl)benzenepropanoic acid.

15 "Compound F" refers to 3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)benzenepropanoic acid.

"Alkyl" refers to a branched or unbranched saturated hydrocarbon chain comprising a designated number of carbon atoms. For example, C₁-C₉ alkyl is a straight or branched hydrocarbon chain containing 1 to 9 carbon atoms, and
20 includes but is not limited to substituents such as methyl, ethyl, propyl, iso-propyl, butyl, iso-butyl, tert-butyl, n-pentyl, n-hexyl, and the like, unless otherwise indicated.

"Alkenyl" refers to a branched or unbranched unsaturated hydrocarbon chain comprising a designated number
25 of carbon atoms. For example, C₂-C₉ alkenyl is a straight or

WO 02/057222

PCT/US02/01205

branched hydrocarbon chain containing 2 to 9 carbon atoms having at least one double bond, and includes but is not limited to substituents such as ethenyl, propenyl, isopropenyl, butenyl, iso-butenyl, tert-butenyl, n-pentenyl, n-
5 hexenyl, and the like, unless otherwise indicated.

"Alkoxy" refers to the group -OR wherein R is alkyl as herein defined. Preferably, R is a branched or unbranched saturated hydrocarbon chain containing 1 to 9 carbon atoms.

"Carbocycle" refers to a hydrocarbon, cyclic moiety
10 having one or more closed ring(s) that is/are alicyclic, aromatic, fused and/or bridged. Examples include cyclopropane, cyclobutane, cyclopentane, cyclohexane, cycloheptane, cyclopentene, cyclohexene, cycloheptene, cyclooctene, benzyl, naphthene, anthracene, phenanthracene,
15 biphenyl and pyrene.

"Aryl" refers to an aromatic, hydrocarbon cyclic moiety having one or more closed rings. Examples include, without limitation, phenyl, benzyl, naphthyl, anthracenyl, phenanthracenyl, biphenyl and pyrenyl.

20 "Heterocycle" refers to a cyclic moiety having one or more closed rings that is/are alicyclic, aromatic, fused and/or bridged, with one or more heteroatoms (for example, sulfur, nitrogen or oxygen) in at least one of the rings. Examples include, without limitation, pyrrolidine, pyrrole,

WO 02/057222

PCT/US02/01205

thiazole, thiophene, piperidine, pyridine, isoxazolidine and isoxazole.

"Heteroaryl" refers to an aromatic, cyclic moiety having one or more closed rings with one or more heteroatoms (for example, sulfur, nitrogen or oxygen) in at least one of the rings. Examples include, without limitation, pyrrole, thiophene, pyridine and isoxazole.

"Derivative" refers to a substance produced from another substance either directly or by modification or partial substitution.

"Effective amount" refers to the amount required to produce the desired effect, for example, to inhibit NAALADase enzyme activity and/or angiogenesis, to effect neuronal activity or TGF- β activity, and/or to treat glutamate abnormality, compulsive disorder, prostate disease, cancer or glaucoma.

"Electromagnetic radiation" includes without limitation radiation having the wavelength of 10^{-20} to 10^0 meters. Examples include, without limitation, gamma radiation (10^{-20} to 10^{-13} m), X-ray radiation (10^{-11} to 10^{-9} m), ultraviolet light (10 nm to 400 nm), visible light (400 nm to 700 nm), infrared radiation (700 nm to 1.0 mm) and microwave radiation (1 mm to 30 cm).

"Halo" refers to at least one fluoro, chloro, bromo or iodo moiety.

WO 02/057222

PCT/US02/01205

"Isosteres" refer to elements, functional groups, substitutents, molecules or ions having different molecular formulae but exhibiting similar or identical physical properties. For example, tetrazole is an isostere of
5 carboxylic acid because it mimics the properties of carboxylic acid even though they both have different molecular formulae. Typically, two isosteric molecules have similar or identical volumes and shapes. Ideally, isosteric compounds should be isomorphic and able to co-crystallize.
10 Other physical properties that isosteric compounds usually share include boiling point, density, viscosity and thermal conductivity. However, certain properties are usually different: dipolar moments, polarity, polarization, size and shape since the external orbitals may be hybridized
15 differently. The term "isosteres" encompasses "bioisosteres".

"Bioisosteres" are isosteres that, in addition to their physical similarities, share some common biological properties. Typically, bioisosteres interact with the same
20 recognition site or produce broadly similar biological effects.

"Carboxylic acid isosteres" include without limitation direct derivatives such as hydroxamic acids, acyl-cyanamides and acylsulfonamides; planar acidic heterocycles such as
25 tetrazoles, mercaptoazoles, sulfinylazoles, sulfonylazoles,

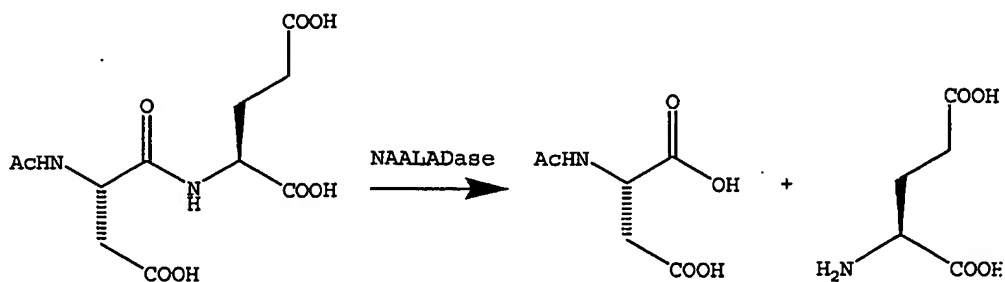
WO 02/057222

PCT/US02/01205

WO 02/057222

PCT/US02/01205

21



Catabolism of NAAG by NAALADase

NAALADase has been assigned to the M28 peptidase family and is also called PSMA or human GCP II, EC number 3.4.17.21. It is believed that NAALADase is a co-catalytic zinc/zinc metallopeptidase. NAALADase shows a high affinity for NAAG with a K_m of 540 nM. If NAAG is a bioactive peptide, then NAALADase may serve to inactivate NAAG'S synaptic action. Alternatively, if NAAG functions as a precursor for glutamate, the primary function of NAALADase may be to regulate synaptic glutamate availability.

"Pharmaceutically acceptable carrier" refers to any carrier, diluent, excipient, wetting agent, buffering agent, suspending agent, lubricating agent, adjuvant, vehicle, delivery system, emulsifier, disintegrant, absorbent, preservative, surfactant, colorant, flavorant, or sweetener, preferably non-toxic, that would be suitable for use in a pharmaceutical composition.

WO 02/057222

PCT/US02/01205

"Pharmaceutically acceptable equivalent" includes, without limitation, pharmaceutically acceptable salts, hydrates, metabolites, prodrugs and isosteres. Many pharmaceutically acceptable equivalents are expected to have
5 the same or similar *in vitro* or *in vivo* activity as the compounds of the invention.

"Pharmaceutically acceptable salt" refers to a salt of the inventive compounds which possesses the desired pharmacological activity and which is neither biologically
10 nor otherwise undesirable. The salt can be formed with acids that include, without limitation, acetate, adipate, alginate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, citrate, camphorate, camphorsulfonate, cyclopentanepropionate, digluconate, dodecylsulfate,
15 ethanesulfonate, fumarate, glucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxyethane-sulfonate, lactate, maleate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, oxalate, thiocyanate, tosylate and undecanoate.
20 Examples of a base salt include ammonium salts, alkali metal salts such as sodium and potassium salts, alkaline earth metal salts such as calcium and magnesium salts, salts with organic bases such as dicyclohexylamine salts, N-methyl-D-glucamine, and salts with amino acids such as arginine and
25 lysine. Basic nitrogen-containing groups can be

WO 02/057222

PCT/US02/01205

quarternized with agents including lower alkyl halides such as methyl, ethyl, propyl and butyl chlorides, bromides and iodides; dialkyl sulfates such as dimethyl, diethyl, dibutyl and diamyl sulfates; long chain halides such as decyl, 5 lauryl, myristyl and stearyl chlorides, bromides and iodides; and aralkyl halides such as benzyl and phenethyl bromides.

"Prodrug" refers to a derivative of the inventive compounds that undergoes biotransformation, such as 10 metabolism, before exhibiting its pharmacological effect(s). The prodrug is formulated with the objective(s) of improved chemical stability, improved patient acceptance and compliance, improved bioavailability, prolonged duration of action, improved organ selectivity, improved formulation 15 (e.g., increased hydrosolubility), and/or decreased side effects (e.g., toxicity). The prodrug can be readily prepared from the inventive compounds using methods known in the art, such as those described by *Burger's Medicinal Chemistry and Drug Chemistry*, Fifth Ed., Vol. 1, pp. 172- 20 178, 949-982 (1995).

"Radiosensitizer" refers to a low molecular weight compound administered to animals in therapeutically effective amounts to promote the treatment of diseases that are treatable with electromagnetic radiation. Diseases that 25 are treatable with electromagnetic radiation include,

WO 02/057222

PCT/US02/01205

without limitation, neoplastic diseases, benign and malignant tumors, and cancerous cells. Electromagnetic radiation treatment of other diseases not listed herein are also contemplated by this invention.

5 "Inhibition," in the context of enzymes, refers to reversible enzyme inhibition such as competitive, uncompetitive and non-competitive inhibition. Competitive, uncompetitive and non-competitive inhibition can be distinguished by the effects of an inhibitor on the reaction
10 kinetics of an enzyme. Competitive inhibition occurs when the inhibitor combines reversibly with the enzyme in such a way that it competes with a normal substrate for binding at the active site. The affinity between the inhibitor and the enzyme may be measured by the inhibitor constant, K_i , which
15 is defined as:

$$K_i = \frac{[E][I]}{[EI]}$$

wherein [E] is the concentration of the enzyme, [I] is the
20 concentration of the inhibitor, and [EI] is the concentration of the enzyme-inhibitor complex formed by the reaction of the enzyme with the inhibitor. Unless otherwise specified, K_i as used herein refers to the affinity between the inventive compounds and NAALADase. "IC₅₀" is a related
25 term used to define the concentration or amount of a

WO 02/057222

PCT/US02/01205

compound that is required to cause a 50% inhibition of the target enzyme.

"NAALADase inhibitor" refers to any compound that inhibits NAALADase enzyme activity. Preferably, a NAALADase
5 inhibitor exhibits a K_i of less than 100 μM , more preferably less than 10 μM , and even more preferably less than 1 μM , as determined using any appropriate assay known in the art.

"Isomers" refer to compounds having the same number and kind of atoms, and hence the same molecular weight, but
10 differing in respect to the arrangement or configuration of the atoms.

"Optical isomers" refer to enantiomers or diastereoisomers.

"Stereoisomers" are isomers that differ only in the
15 arrangement of the atoms in space.

"Diastereoisomers" are stereoisomers that are not mirror images of each other. Diastereoisomers occur in compounds having two or more asymmetric carbon atoms; thus, such compounds have 2^n optical isomers, where n is the number
20 of asymmetric carbon atoms.

"Enantiomers" are a pair of stereoisomers that are non-superimposable mirror images of each other. Enantiomers result from the presence of one or more asymmetric carbon atoms in the compound (e.g., glyceraldehyde, lactic acid, sugars, tartaric acid, amino acids).
25

WO 02/057222

PCT/US02/01205

"Enantiomer-enriched" refers to a mixture in which one enantiomer predominates.

"Racemic mixture means a mixture containing equal amounts of individual enantiomers.

5 "Non-racemic mixture" is a mixture containing unequal amounts of enantiomers.

"Angiogenesis" refers to the process whereby new capillaries are formed. "Inhibition" of angiogenesis may be measured by many parameters in accordance with this
10 invention and, for instance, may be assessed by delayed appearance of neovascular structures, slowed development of neovascular structures, decreased occurrence of neovascular structures, slowed or decreased severity of angiogenesis-dependent disease effects, arrested angiogenic growth, or
15 regression of previous angiogenic growth. In the extreme, complete inhibition is referred to herein as prevention. In relation to angiogenesis or angiogenic growth, "prevention" refers to no substantial angiogenesis or angiogenic growth if none had previously occurred, or no substantial further
20 angiogenesis or angiogenic growth if growth had previously occurred.

"Angiogenesis-dependent disease" includes, without limitation, rheumatoid arthritis, cardiovascular diseases, neovascular diseases of the eye, peripheral vascular

WO 02/057222

PCT/US02/01205

disorders, dermatologic ulcers and cancerous tumor growth, invasion and metastasis.

"Animal" refers to a living organism having sensation and the power of voluntary movement, and which requires for
5 its existence oxygen and organic food. Examples include, without limitation, members of the human, equine, porcine, bovine, murine, canine, or feline species. In the case of a human, an "animal" may also be referred to as a "patient".

"Mammal" refers to a warm-blooded vertebrate animal.

10 "Anxiety" includes without limitation the unpleasant emotion state consisting of psychophysiological responses to anticipation of unreal or imagined danger, ostensibly resulting from unrecognized intrapsychic conflict. Physiological concomitants include increased heart rate,
15 altered respiration rate, sweating, trembling, weakness, and fatigue; psychological concomitants include feelings of impending danger, powerlessness, apprehension, and tension. Dorland's Illustrated Medical Dictionary, W.B. Saunders Co., 27th ed. (1988).

20 "Anxiety Disorder" includes without limitation mental disorders in which anxiety and avoidance behavior predominate. Dorland's Illustrated Medical Dictionary, W.B. Saunders Co., 27th ed. (1988). Examples include without
25 limitation panic attack, agoraphobia, panic disorder, acute stress disorder, chronic stress disorder, specific phobia,

WO 02/057222

PCT/US02/01205

simple phobia, social phobia, substance induced anxiety disorder, organic anxiety disorder, obsessive compulsive disorder, post-traumatic stress disorder, generalized anxiety disorder, and anxiety disorder NOS. Other anxiety disorders are characterized in Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association 4th ed. 1994).

"Attention Deficit Disorder" or "ADD" refers to a disorder characterized by developmentally inappropriate inattention and impulsiveness, with or without hyperactivity. Inattention means a failure to finish tasks started, easily distracted, seeming lack of attention, and difficulty concentrating on tasks requiring sustained attention. Impulsiveness means acting before thinking, difficulty taking turns, problems organizing work, and constant shifting from one activity to another. Hyperactivity means difficulty staying seated and sitting still, and running or climbing excessively.

"Cancer" includes, without limitation, ACTH-producing tumors, acute lymphocytic leukemia, acute nonlymphocytic leukemia, cancer of the adrenal cortex, bladder cancer, brain cancer, breast cancer, cervix cancer, chronic lymphocytic leukemia, chronic myelocytic leukemia, colorectal cancer, cutaneous T-cell lymphoma, endometrial cancer, esophageal cancer, Ewing's sarcoma, gallbladder

WO 02/057222

PCT/US02/01205

cancer, hairy cell leukemia, head and neck cancer, Hodgkin's lymphoma, Kaposi's sarcoma, kidney cancer, liver cancer, lung cancer (small and/or non-small cell), malignant peritoneal effusion, malignant pleural effusion, melanoma, mesothelioma, multiple myeloma, neuroblastoma, non-Hodgkin's lymphoma, osteosarcoma, ovary cancer, ovary (germ cell) cancer, pancreatic cancer, penis cancer, prostate cancer, retinoblastoma, skin cancer, soft-tissue sarcoma, squamous cell carcinomas, stomach cancer, testicular cancer, thyroid cancer, trophoblastic neoplasms, cancer of the uterus, vaginal cancer, cancer of the vulva, and Wilm's tumor.

"Compulsive disorder" refers to any disorder characterized by irresistible impulsive behavior. Examples of compulsive disorders include without limitation substance dependence, eating disorders, pathological gambling, Attention Deficit Disorder ("ADD"), and Tourette's syndrome.

"Demyelinating disease" refers to any disease involving damage to or removal of the myelin sheath naturally surrounding nerve tissue, such as that defined in U.S. Patent No. 5,859,046 and International Publication No. WO 98/03178, herein incorporated by reference. Examples include without limitation peripheral demyelinating diseases (such as Guillain-Barré syndrome, peripheral neuropathies and Charcot-Marie Tooth disease) and central demyelinating diseases (such as multiple sclerosis).

WO 02/057222

PCT/US02/01205

"Disease" refers to any deviation from or interruption of the normal structure or function of any part, organ or system (or combinations) of the body that is manifested by a characteristic set of symptoms and signs and whose etiology, pathology, and prognosis may be known or unknown. Dorland's Illustrated Medical Dictionary, (W.B. Saunders Co. 27th ed. 1988).

"Disorder" refers to any derangement or abnormality of function; a morbid physical or mental state. Dorland's Illustrated Medical Dictionary, (W.B. Saunders Co. 27th ed. 1988).

"Drug dependence" refers to a psychologic addiction or a physical tolerance to a drug. Tolerance means a need to increase the dose progressively in order to produce the effect originally achieved by smaller amounts.

"Eating disorder" refers to compulsive overeating, obesity or severe obesity. Obesity means body weight of 20% over standard height-weight tables. Severe obesity means over 100% overweight.

"Glaucoma" includes without limitation chronic (idiopathic) open-angle glaucomas (e.g., high-pressure, normal-pressure); pupillary block glaucomas (e.g., acute angle-closure, subacute angle-closure, chronic angle-closure, combined-mechanism); developmental glaucomas (e.g., congenital (infantile), juvenile, Axenfeld-Rieger syndrome,

WO 02/057222

PCT/US02/01205

Peters' anomaly, Aniridia); glaucomas associated with other ocular disorders (e.g., glaucomas associated with disorders of the corneal endothelium, iris, ciliary body, lens, retina, choroid and vitreous); glaucomas associated with elevated
5 episcleral venous pressure (e.g., systemic diseases with associated elevated intraocular pressure and glaucoma, corticosteroid-induced glaucoma); glaucomas associated with inflammation and trauma (e.g., glaucomas associated with keratitis, episcleritis, scleritis, uveitis, ocular trauma
10 and hemorrhage); glaucomas following intraocular surgery (e.g., ciliary block (malignant) glaucoma, glaucomas in aphakia and pseudophakia, glaucomas associated with corneal surgery, glaucomas associated with vitreoretinal surgery).

"Glutamate abnormality" refers to any disease,
15 disorder, or condition in which glutamate is implicated, including pathological conditions involving elevated levels of glutamate. Examples of glutamate abnormalities include, without limitation, compulsive disorder, spinal cord injury, epilepsy, stroke, ischemia, demyelinating disease,
20 Alzheimer's disease, Parkinson's disease, ALS, Huntington's disease, schizophrenia, pain, peripheral neuropathy (including but not limited to diabetic neuropathy), traumatic brain injury, neuronal insult, inflammatory disease, anxiety, anxiety disorder, memory impairment and
25 glaucoma.

WO 02/057222

PCT/US02/01205

"Ischemia" refers to localized tissue anemia due to obstruction of the inflow of arterial blood. Global ischemia occurs when blood flow ceases for a period of time, as may result from cardiac arrest. Focal ischemia occurs
5 when a portion of the body, such as the brain, is deprived of its normal blood supply, such as may result from thromboembolytic occlusion of a cerebral vessel, traumatic head injury, edema or brain tumor. Even if transient, both global and focal ischemia can produce widespread neuronal
10 damage. Although nerve tissue damage occurs over hours or even days following the onset of ischemia, some permanent nerve tissue damage may develop in the initial minutes following cessation of blood flow to the brain. Much of this damage is attributed to glutamate toxicity and
15 secondary consequences of reperfusion of the tissue, such as the release of vasoactive products by damaged endothelium, and the release of cytotoxic products, such as free radicals and leukotrienes, by the damaged tissue.

"Memory impairment" refers to a diminished mental
20 registration, retention or recall of past experiences, knowledge, ideas, sensations, thoughts or impressions. Memory impairment may affect short and long-term information retention, facility with spatial relationships, memory (rehearsal) strategies, and verbal retrieval and production.
25 Common causes of memory impairment are age, severe head

WO 02/057222

PCT/US02/01205

trauma, brain anoxia or ischemia, alcoholic-nutritional diseases, drug intoxications and neurodegenerative diseases. For example, memory impairment is a common feature of neurodegenerative diseases such as Alzheimer's disease and

5 senile dementia of the Alzheimer type. Memory impairment also occurs with other kinds of dementia such as multi-infarct dementia, a senile dementia caused by cerebrovascular deficiency, and the Lewy-body variant of Alzheimer's disease with or without association with

10 Parkinson's disease. Creutzfeldt-Jakob disease is a rare dementia with which memory impairment is associated. It is a spongiform encephalopathy caused by the prion protein; it may be transmitted from other sufferers or may arise from gene mutations. Loss of memory is also a common feature of

15 brain-damaged patients. Brain damage may occur, for example, after a classical stroke or as a result of an anaesthetic accident, head trauma, hypoglycemia, carbon monoxide poisoning, lithium intoxication, vitamin (B₁, thiamine and B₁₂) deficiency, or excessive alcohol use.

20 Korsakoff's amnesic psychosis is a rare disorder characterized by profound memory loss and confabulation, whereby the patient invents stories to conceal his or her memory loss. It is frequently associated with excessive alcohol intake. Memory impairment may furthermore be age-

25 associated; the ability to recall information such as names,

WO 02/057222

PCT/US02/01205

places and words seems to decrease with increasing age. Transient memory loss may also occur in patients, suffering from a major depressive disorder, after electro-convulsive therapy.

5 "Mental disorder" refers to any clinically significant behavioral or psychological syndrome characterized by the presence of distressing symptoms or significant impairment of functioning. Mental disorders are assumed to result from some psychological or organic dysfunction of the individual;
10 the concept does not include disturbances that are essentially conflicts between the individual and society (social deviance).

"Metastasis" refers to "[t]he ability of cells of a cancer to disseminate and form new foci of growth at
15 noncontiguous sites (i.e., to form metastases)." See Hill, R.P., "Metastasis", *The Basic Science of Oncology*, Tannock et al., Eds., McGraw-Hill, New York, pp. 178-195 (1992), herein incorporated by reference. "The transition from *in situ* tumor growth to metastatic disease is defined by the ability
20 of tumor cells of the primary site to invade local tissues and to cross tissue barriers ... To initiate the metastatic process, carcinoma cells must first penetrate the epithelial basement membrane and then invade the interstitial stroma. ... For distant metastases, intravasation requires tumor
25 cell invasion of the subendothelial basement membrane that

WO 02/057222

PCT/US02/01205

must also be negotiated during tumor cell extravasation ...
The development of malignancy is also associated with tumor-
induced angiogenesis [which] not only allows for expansion
of the primary tumors, but also permits easy access to the
5 vascular compartment due to defects in the basement
membranes of newly formed vessels." See Aznavoorian et al.,
Cancer (1993) 71:1368-1383, herein incorporated by
reference.

"Nervous insult" refers to any damage to nervous tissue
10 and any disability or death resulting therefrom. The cause
of nervous insult may be metabolic, toxic, neurotoxic,
iatrogenic, thermal or chemical, and includes without
limitation ischemia, hypoxia, cerebrovascular accident,
trauma, surgery, pressure, mass effect, hemorrhage,
15 radiation, vasospasm, neurodegenerative disease,
neurodegenerative process, infection, Parkinson's disease,
ALS, myelination/demyelination processes, epilepsy,
cognitive disorder, glutamate abnormality and secondary
effects thereof.

20 "Nervous tissue" refers to the various components that
make up the nervous system, including without limitation
neurons, neural support cells, glia, Schwann cells,
vasculature contained within and supplying these structures,
the central nervous system, the brain, the brain stem, the
25 spinal cord, the junction of the central nervous system with

WO 02/057222

PCT/US02/01205

the peripheral nervous system, the peripheral nervous system and allied structures.

"Neuropathy" refers to any disease or malfunction of the nerves. Neuropathy includes, without limitation, 5 peripheral neuropathy, diabetic neuropathy, autonomic neuropathy and mononeuropathy. Peripheral neuropathy may be idiopathic or induced by any causes including diseases (for example, amyloidosis, alcoholism, HIV, syphilis, virus, autoimmune disorder, cancer, porphyria, 10 arachnoiditis, post herpetic neuralgia, Guillain-Barré syndrome, diabetes including type I and type II diabetes), chemicals (for example, toxins, lead, dapsone, vitamins, paclitaxel chemotherapy, HAART therapy) and physical injuries to a particular nerve or 15 nerve plexus (for example, trauma, compression, constriction).

"Neuroprotective" refers to the effect of reducing, arresting or ameliorating nervous insult, and protecting, resuscitating or reviving nervous tissue that has suffered 20 nervous insult.

"Pain" refers to localized sensations of discomfort, distress or agony, resulting from the stimulation of specialized nerve endings. It serves as a protective mechanism insofar as it induces the sufferer to remove or

WO 02/057222

PCT/US02/01205

withdraw from the source. Dorland's Illustrated Medical Dictionary, (W.B. Saunders Co. 27th ed. 1988). Examples of pain include, without limitation, acute, chronic, cancer, burn, incisional, inflammatory, neuropathic and back pain.

5 "Neuropathic pain" refers to a condition of pain associated with a nerve injury. Depending on the particular syndrome, the pain may be due to alterations of the brain or spinal cord or may be due to abnormalities in the nerve itself. Neuropathic pain may be idiopathic or induced by
10 any causes including diseases (for example, amyloidosis, alcoholism, HIV, syphilis, virus, autoimmune disorder, cancer, porphyria, arachnoiditis, post herpetic neuralgia, Guillain-Barré syndrome, diabetes including type I and type II diabetes), chemicals (for example, toxins, lead, dapsone,
15 vitamins, paclitaxel chemotherapy, HAART therapy) and physical injuries to a particular nerve or nerve plexus (for example, trauma, compression, constriction).

 "Pathological gambling" refers to a condition characterized by a preoccupation with gambling. Similar to
20 psychoactive substance abuse, its effects include development of tolerance with a need to gamble progressively larger amounts of money, withdrawal symptoms, and continued gambling despite severe negative effects on family and occupation.

WO 02/057222

PCT/US02/01205

"Prostate disease" refers to any disease affecting the prostate. Examples of prostate disease include without limitation prostate cancer such as adenocarcinoma and metastatic cancers of the prostate; and conditions
5 characterized by abnormal growth of prostatic epithelial cells such as benign prostatic hyperplasia.

"Schizophrenia" refers to a mental disorder or group of mental disorders characterized by disturbances in form and content of thought (loosening of associations, delusions,
10 hallucinations), mood (blunted, flattened, inappropriate affect), sense of self and relationship to the external world (loss of ego boundaries, dereistic thinking, and autistic withdrawal), and behavior (bizarre, apparently purposeless, and stereotyped activity or inactivity).
15 Examples of schizophrenia include, without limitation, acute, ambulatory, borderline, catatonic, childhood, disorganized, hebephrenic, latent, nuclear, paranoid, paraphrenic, prepsychotic, process, pseudoneurotic, pseudopsychopathic, reactive, residual, schizo-affective and
20 undifferentiated schizophrenia. Dorland's Illustrated Medical Dictionary, (W.B. Saunders Co. 27th ed. 1988).

"TGF- β " refers to transforming growth factor beta. TGF- β is recognized as a prototype of multifunctional growth factors. It regulates various cell and tissue functions,
25 including cell growth and differentiation, angiogenesis,

WO 02/057222

PCT/US02/01205

wound healing, immune function, extracellular matrix production, cell chemotaxis, apoptosis and hematopoiesis.

"TGF- β abnormality" refers to any disease, disorder or condition in which TGF- β is implicated, including diseases
5 disorders and conditions characterized by an abnormal level of TGF- β .

"Abnormal level of TGF- β " refers to a measurable variance from normal levels of TGF- β , as determined by one of ordinary skill in the art using known techniques.

10 "Therapeutic window of opportunity" or "window" refers, in relation to stroke, to the maximal delay between the onset of stroke and the initiation of efficacious therapy.

"Tourette's syndrome" refers to an autosomal multiple tic disorder characterized by compulsive swearing, multiple
15 muscle tics and loud noises. Tics are brief, rapid, involuntary movements that can be simple or complex; they are stereotyped and repetitive, but not rhythmic. Simple tics, such as eye blinking, often begin as nervous mannerisms. Complex tics often resemble fragments of normal
20 behavior.

Unless otherwise defined in conjunction with specific diseases or disorders, "treating" refers to:

(i) preventing a disease, disorder or condition from occurring in an animal that may be predisposed to the

WO 02/057222

PCT/US02/01205

disease, disorder and/or condition but has not yet been diagnosed as having it;

(ii) inhibiting the disease, disorder or condition, i.e., arresting its development; and/or

5 (iii) relieving the disease, disorder or condition, i.e., causing regression of the disease, disorder and/or condition.

"Treating ALS" refers to:

(i) preventing ALS from occurring in an animal that may
10 be predisposed to ALS but has not yet been diagnosed as having it;

(ii) inhibiting ALS, i.e. arresting its development;

(iii) relieving ALS, i.e. causing regression of the disease, disorder and/or condition;

15 (iv) delaying onset of ALS or ALS symptom(s);

(v) slowing progression of ALS or ALS symptom(s);

(vi) prolonging survival of an animal suffering from ALS; and/or

(vii) attenuating ALS symptom(s).

20 "Treating Huntington's disease" refers to:

(i) preventing Huntington's disease from occurring in an animal that may be predisposed to Huntington's disease but has not yet been diagnosed as having it;

25 (ii) inhibiting or slowing Huntington's disease,

WO 02/057222

PCT/US02/01205

e.g. arresting its development;

(iii) relieving Huntington's disease, e.g. causing its regression;

(iv) improving motor coordination in an animal
5 having Huntington's disease; and/or

(v) prolonging the survival of an animal having Huntington's disease.

"Treating substance dependence" refers to preventing relapse; reducing craving; suppressing
10 tolerance; preventing, inhibiting and/or relieving withdrawal; attenuating sensitization; preventing, inhibiting (i.e. arresting development of) and/or relieving (i.e. causing regression of) substance-induced neurotoxicity; and/or preventing, inhibiting and/or
15 relieving fetal alcohol syndrome.

"Craving" refers to a strong desire for a substance and/or a compelling urge and/or an irresistible impulse to use a substance.

"Dependence" refers to a maladaptive pattern of
20 substance use, leading to clinically significant impairment or distress. Dependence is typically characterized by tolerance and/or withdrawal. Substances for which dependence may be developed

WO 02/057222

PCT/US02/01205

include, without limitation, depressants (opioids, synthetic narcotics, barbiturates, glutethimide, methyprylon, ethchlorvynol, methaqualone, alcohol); anxiolytics (diazepam, chlordiazepoxide, alprazolam, oxazepam, temazepam); stimulants (amphetamine, methamphetamine, cocaine); and hallucinogens (LSD, mescaline, peyote, marijuana).

"Relapse" refers to a return to substance use after a period of abstinence, often accompanied by reinstatement.

"Reinstatement" refers to a return to a preexisting level of use and dependence in a person who has resumed substance use following a period of abstinence.

"Sensitization" refers to a condition in which the response to a substance increases with repeated use.

"Tolerance" refers to an acquired reaction to a substance characterized by diminished effect with continued use of the same dose and/or a need for increased doses to achieve intoxication or desired effect previously achieved by lower doses. Both physiological and psychosocial factors may contribute to the development of tolerance. With respect to physiological tolerance, metabolic and/or functional tolerance may develop. By increasing the rate of metabolism of the substance, the body may be able to

WO 02/057222

PCT/US02/01205

eliminate the substance more readily. Functional tolerance is defined as a decrease in sensitivity of the central nervous system to the substance.

"Withdrawal" refers to a syndrome characterized by
5 untoward physical changes that occur following cessation of or reduction in substance use, or administration of a pharmacologic antagonist.

One of ordinary skill in the art will recognize that there are alternative nomenclatures, nosologies and
10 classification systems for the diseases, disorders and conditions defined above, and that such systems evolve with medical scientific progress.

Unless the context clearly dictates otherwise, the definitions of singular terms may be extrapolated to apply
15 to their plural counterparts as they appear in the application; likewise, the definitions of plural terms may be extrapolated to apply to their singular counterparts as they appear in the application.

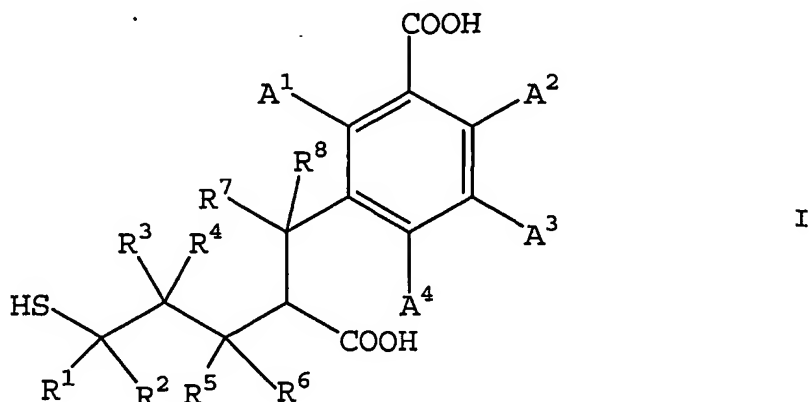
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COMPOUNDS OF THE INVENTION

This invention relates to compounds of formula I

WO 02/057222

PCT/US02/01205



or a pharmaceutically acceptable equivalent of said compound, wherein:

R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 and R^8 are independently
 5 hydrogen or C_1 - C_3 alkyl;

A^1 , A^2 , A^3 and A^4 are independently hydrogen, C_1 - C_6 alkyl, C_1 - C_6 alkoxy, halo, nitro, phenyl, phenoxy, benzyl, benzyloxy or $-COOH$, or any adjacent two of A^2 , A^3 and A^4 form with the benzene ring a fused 5- or 6-membered carbocyclic or
 10 heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s).

In one embodiment, R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 and R^8 are independently hydrogen or methyl; and A^1 , A^2 , A^3 and A^4 are
 15 independently hydrogen, C_1 - C_4 alkyl, C_1 - C_2 alkoxy, halo, nitro, phenyl, phenoxy, benzyloxy, nitro or $-COOH$.

In another embodiment, any adjacent two of A^2 , A^3 and A^4 form with the benzene ring a fused 5- or 6-membered

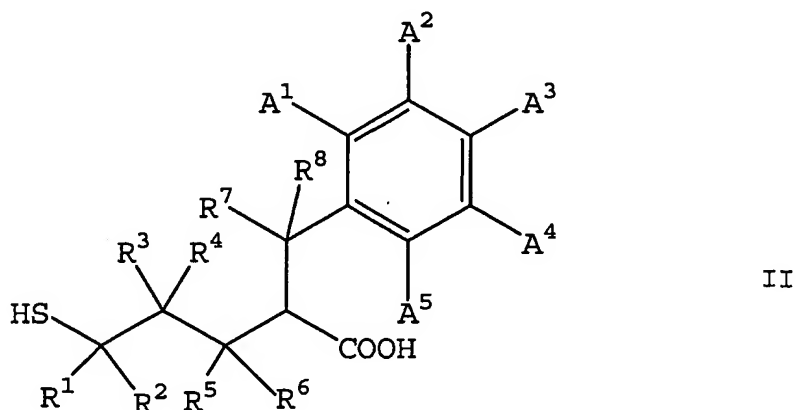
WO 02/057222

PCT/US02/01205

carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s).

This invention further relates to a compound of formula

5 II



or a pharmaceutically acceptable equivalent of said compound, wherein:

R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 and R^8 are independently
10 hydrogen or C₁-C₃ alkyl; and

A^1 , A^2 , A^3 , A^4 and A^5 are independently hydrogen, C₁-C₆ alkyl, C₁-C₆ alkoxy, C₁-C₃ perhaloalkyl, phenyl, phenoxy, benzyl, benzyloxy, hydroxy, halo, cyano, nitro, -SO₂R⁹,
- (C=O)NR⁹R¹⁰, - (C=O)NR⁹(CH₂)_nCOOH, -NR⁹(C=O)R¹⁰, - (CH₂)_nCOOH or
15 -COOH, or any adjacent two of A^1 , A^2 , A^3 , A^4 and A^5 form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring

WO 02/057222

PCT/US02/01205

containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s);

R⁹ and R¹⁰ are independently hydrogen, C₁-C₆ alkyl, phenyl or benzyl; and

5 n is 1-3;

provided that if A¹, A³ and A⁵ are independently hydrogen, C₁-C₆ alkyl, C₁-C₆ alkoxy, halo, nitro, phenyl, phenoxy, benzyl, benzyloxy or -COOH, then neither A² nor A⁴ are -COOH; and provided that if any adjacent two of A³, A⁴
10 and A⁵ form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s), then A² is not -COOH.

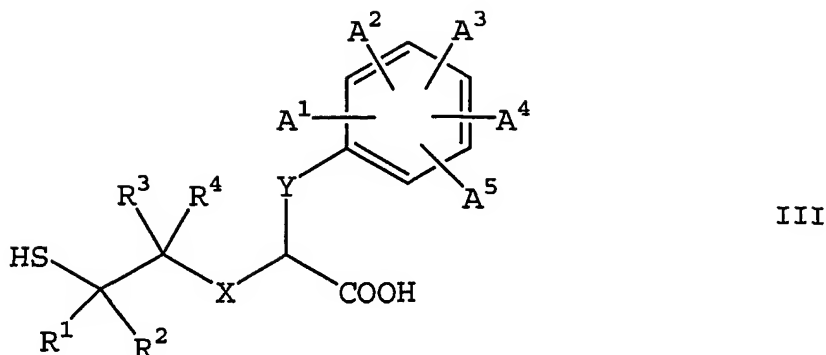
In one embodiment, R¹, R², R³, R⁴, R⁵, R⁶, R⁷ and R⁸ are
15 each hydrogen; A¹, A², A³, A⁴ and A⁵ are independently hydrogen, C₁-C₄ alkyl, C₁-C₂ alkoxy, C₁-C₂ perhaloalkyl, phenyl, phenoxy, hydroxy, halo, cyano, nitro, -SO₂R⁹, - (C=O)NR⁹R¹⁰, - (C=O)NR⁹(CH₂)COOH, -NR⁹(C=O)R¹⁰ or - (CH₂)COOH; and R⁹ and R¹⁰ are independently hydrogen, methyl or benzyl.

20 In another embodiment, any adjacent two of A¹, A², A³, A⁴ and A⁵ form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s).

25 This invention also relates to a compound of formula III

WO 02/057222

PCT/US02/01205



or a pharmaceutically acceptable equivalent of said compound, wherein:

X and Y are independently $-\text{CR}^5\text{R}^6-$, $-\text{O}-$, $-\text{S}-$ or $-\text{NR}-$,
 5 provided that at least one of X and Y is/are $-\text{CR}^5\text{R}^6-$;

A^1 , A^2 , A^3 , A^4 and A^5 are independently hydrogen, C_1 - C_9 alkyl, C_2 - C_9 alkenyl, C_2 - C_9 alkynyl, aryl, heteroaryl, carbocycle, heterocycle, C_1 - C_9 alkoxy, C_2 - C_9 alkenyloxy, phenoxy, benzyloxy, hydroxy, halo, nitro, cyano, isocyano,
 10 $-\text{COOR}^7$, $-\text{COR}^7$, $-\text{NR}^7\text{R}^8$, $-\text{SR}^7$, $-\text{SOR}^7$, $-\text{SO}_2\text{R}^7$, $-\text{SO}_2(\text{OR}^7)$, $-(\text{C}=\text{O})\text{NR}^7\text{R}^8$, $-(\text{C}=\text{O})\text{NR}^7(\text{CH}_2)_n\text{COOH}$, $-\text{NR}^7(\text{C}=\text{O})\text{R}^8$ or $-(\text{CH}_2)_n\text{COOH}$, or any adjacent two of A^1 , A^2 , A^3 , A^4 and A^5 form with the benzene ring a fused ring that is saturated or unsaturated, aromatic or non-aromatic, and carbocyclic or heterocyclic, said
 15 heterocyclic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s);

n is 1-3;

WO 02/057222

PCT/US02/01205

R, R¹, R², R³, R⁴, R⁵, R⁶, R⁷ and R⁸ are independently hydrogen, C₁-C₉ alkyl, C₂-C₉ alkenyl, C₂-C₉ alkynyl, aryl, heteroaryl, carbocycle or heterocycle; and

said alkyl, alkenyl, alkynyl, aryl, heteroaryl, carbocycle, heterocycle, alkoxy, alkenyloxy, phenoxy, benzyloxy, and fused ring are independently unsubstituted or substituted with one or more substituent(s);

provided that if A¹, A² and A³ are each hydrogen, and A⁴ and A⁵ are each -COOH, then A⁴ is ortho to A⁵; and provided that if Y is -CR⁵R⁶-, then at least one of A¹, A², A³, A⁴ and A⁵ is/are independently phenoxy, benzyloxy, aryl, heteroaryl, carbocycle or heterocycle that is substituted with one or more substituent(s).

In one embodiment, Y is -O-, -S- or -NR-; A¹, A², A³, A⁴ and A⁵ are independently hydrogen, C₁-C₄ alkyl, C₁-C₂ alkoxy, hydroxy, halo, -COOH, -COR⁷, -NR⁷(C=O)R⁸ or -(CH₂)COOH; and R⁷ and R⁸ are independently hydrogen or methyl.

In another embodiment, Y is -CR⁵R⁶-; A¹, A², A³ and A⁴ are each hydrogen; and A⁵ is phenoxy, benzyloxy, aryl, heteroaryl, carbocycle or heterocycle, wherein said phenoxy and benzyloxy are substituted with -COOH, and said aryl, heteroaryl, carbocycle and heterocycle are substituted with one or more substituent(s) selected from the group consisting of cyano and -COOH.

WO 02/057222

PCT/US02/01205

Possible substituents of said alkyl, alkenyl, alkynyl, aryl, heteroaryl, carbocycle, heterocycle, alkoxy, alkenyloxy, phenoxy, benzyloxy, and fused ring include, without limitation, C₁-C₆ alkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, 5 C₁-C₆ alkoxy, C₂-C₆ alkenyloxy, phenoxy, benzyloxy, hydroxy, carboxy, hydroperoxy, carbamido, carbamoyl, carbamyl, carbonyl, carbozoyl, amino, hydroxyamino, formamido, formyl, guanyl, cyano, cyanoamino, isocyano, isocyanato, diazo, azido, hydrazino, triazano, nitrilo, nitro, nitroso, 10 isonitroso, nitrosamino, imino, nitrosimino, oxo, C₁-C₆ alkylthio, sulfamino, sulfamoyl, sulfeno, sulfhydryl, sulfinyl, sulfo, sulfonyl, thiocarboxy, thiocyno, isothiocyno, thioformamido, halo, haloalkyl, chlorosyl, chloryl, perchloryl, trifluoromethyl, iodosyl, iodyl, 15 phosphino, phosphinyl, phospho, phosphono, arsino, selanyl, disilanyl, siloxy, silyl, silylene and carbocyclic and heterocyclic moieties. Carbocyclic moieties include alicyclic and aromatic structures.

Examples of carbocyclic and heterocyclic moieties 20 include, without limitation, phenyl, benzyl, naphthyl, indenyl, azulenyl, fluorenyl, anthracenyl, indolyl, isoindolyl, indolinyl, benzofuranyl, benzothiophenyl, indazolyl, benzimidazolyl, benzthiazolyl, tetrahydrofuranyl, tetrahydropyranyl, pyridyl, pyrrolyl, pyrrolidinyl, 25 pyridinyl, pyrimidinyl, purinyl, quinolinyl, isoquinolinyl,

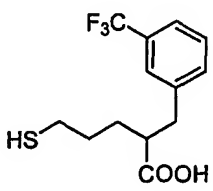
WO 02/057222

PCT/US02/01205

tetrahydroquinolinyl, quinolizinyl, furyl, thiophenyl, imidazolyl, oxazolyl, benzoxazolyl, thiazolyl, isoxazolyl, isotriazolyl, oxadiazolyl, triazolyl, thiadiazolyl, pyridazinyl, pyrimidinyl, pyrazinyl, triazinyl, trithianyl, 5 indolizinyl, pyrazolyl, pyrazolinyl, pyrazolidinyl, thienyl, tetrahydroisoquinolinyl, cinnolinyl, phthalazinyl, quinazolinyl, quinoxalinyl, naphthyridinyl, pteridinyl, carbazolyl, acridinyl, phenazinyl, phenothiazinyl, and phenoxazinyl.

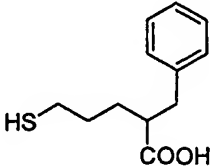
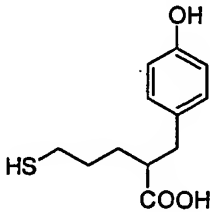
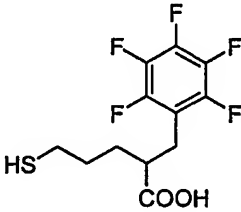
10 Representative compounds of the invention are set forth below in TABLE I.

TABLE I

Compound No.	Structure/Name
1	 <p>alpha-(3-mercaptopropyl)-3-(trifluoromethyl)- benzenepropanoic acid</p>

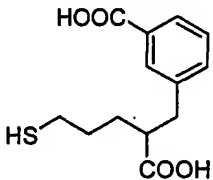
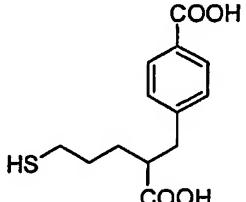
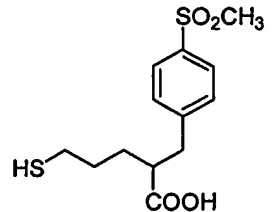
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
2	 <p>alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
3	 <p>4-hydroxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
4	 <p>2,3,4,5,6-pentafluoro-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

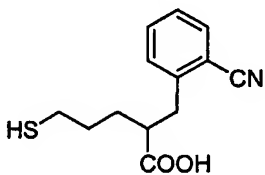
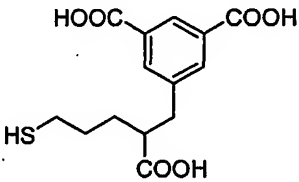
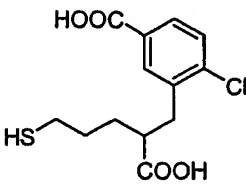
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
5	 <p>3-carboxy-alpha-(3-mercaptopropyl)- benzenepropanoic acid</p>
6	 <p>4-carboxy-alpha-(3-mercaptopropyl)- benzenepropanoic acid</p>
7	 <p>alpha-(3-mercaptopropyl)-4-(methylsulfonyl)- benzenepropanoic acid</p>

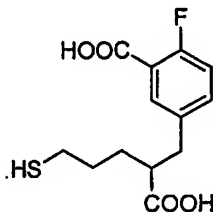
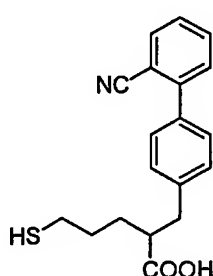
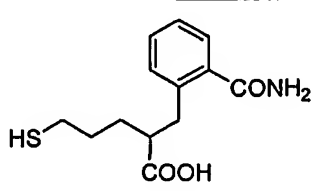
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
8	 <p>2-cyano-alpha-(3-mercaptopropyl)- benzenepropanoic acid</p>
9	 <p>5-(2-carboxy-5-mercaptopentyl)-1,3- benzenedicarboxylic acid</p>
10	 <p>5-carboxy-2-chloro-alpha-(3-mercaptopropyl)- benzenepropanoic acid</p>

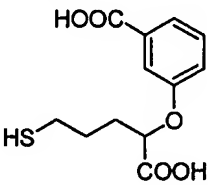
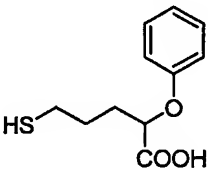
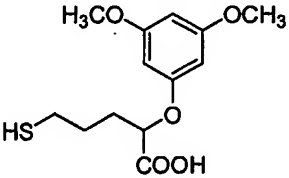
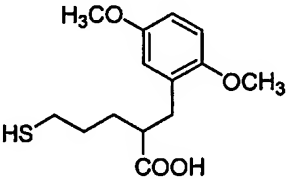
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
11	 <p>3-carboxy-4-fluoro-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
12	 <p>4-(2-cyanophenyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
13	 <p>2-(aminocarbonyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

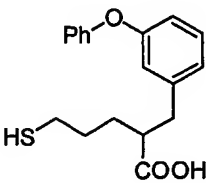
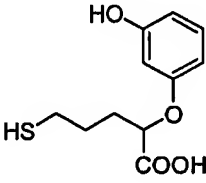
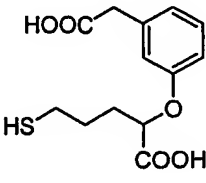
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
14	 <p>3-(1-carboxy-4-mercaptoputoxy)-benzoic acid</p>
15	 <p>5-mercapto-2-phenoxy-pentanoic acid</p>
16	 <p>2-(3,5-dimethoxyphenoxy)-5-mercapto-pentanoic acid</p>
17	 <p>alpha-(3-mercaptoethyl)-2,5-dimethoxy-benzenepropanoic acid</p>

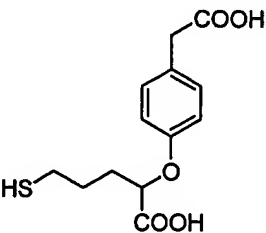
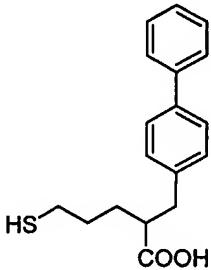
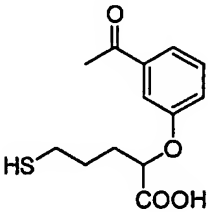
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
18	 <p>alpha-(3-mercaptopropyl)-3-phenoxy-benzenepropanoic acid</p>
19	 <p>2-(3-hydroxyphenoxy)-5-mercapto-pentanoic acid</p>
20	 <p>3-(1-carboxy-4-mercaptoputoxy)-benzeneacetic acid</p>

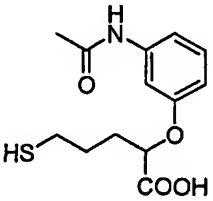
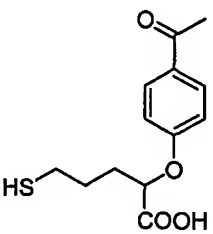
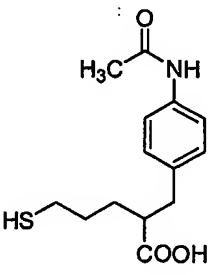
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
21	 <p>4-(1-carboxy-4-mercaptoputoxy)-benzeneacetic acid</p>
22	 <p>alpha-(3-mercaptopropyl)-4-phenyl-benzenepropanoic acid</p>
23	 <p>2-(3-acetylphenoxy)-5-mercapto-pentanoic acid</p>

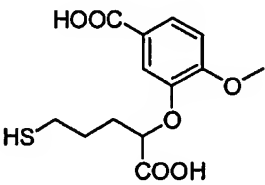
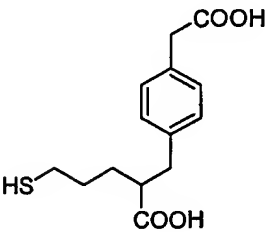
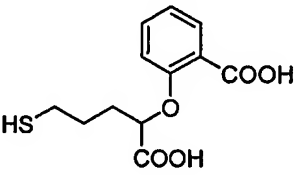
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
24	 <p>2 - [3 - (acetylamino)phenoxy] -5-mercapto-pentanoic acid</p>
25	 <p>2 - (4-acetylphenoxy) -5-mercaptopentanoic acid</p>
26	 <p>4 - (acetylamino) -alpha - (3-mercaptopropyl) - benzenepropanoic acid</p>

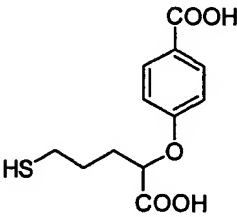
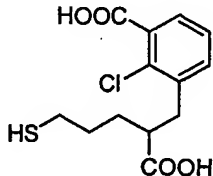
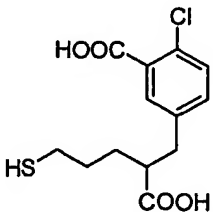
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
27	 <p>3 - (1-carboxy-4-mercaptoputoxy) -4-methoxy-benzoic acid</p>
28	 <p>4 - (carboxymethyl) -alpha - (3-mercaptopropyl) - benzenepropanoic acid</p>
29	 <p>2 - (1-carboxy-4-mercaptoputoxy) -benzoic acid</p>

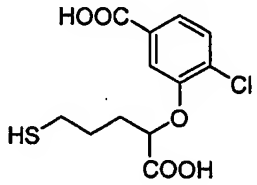
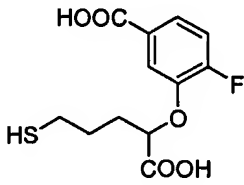
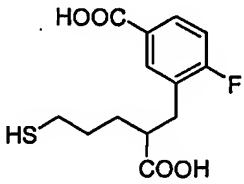
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
30	 <p>4-(1-carboxy-4-mercaptoputoxy)-benzoic acid</p>
31	 <p>3-carboxy-2-chloro-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
32	 <p>3-carboxy-4-chloro-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

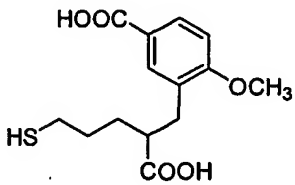
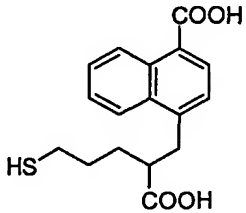
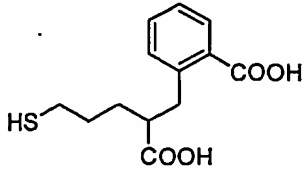
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
33	 <p>3-(1-carboxy-4-mercaptoputoxy)-4-chloro-benzoic acid</p>
34	 <p>3-(1-carboxy-4-mercaptoputoxy)-4-fluoro-benzoic acid</p>
35	 <p>5-carboxy-2-fluoro-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

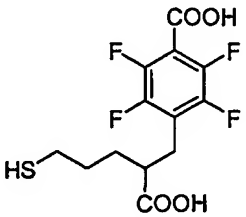
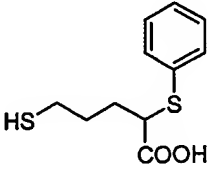
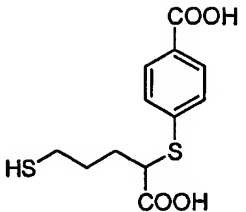
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
36	 <p>5-carboxy-alpha-(3-mercaptopropyl)-2-methoxy-benzenepropanoic acid</p>
37	 <p>4-carboxy-alpha-(3-mercaptopropyl)-1-naphthalenepropanoic acid</p>
38	 <p>2-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

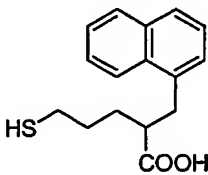
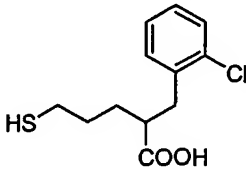
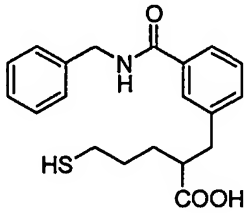
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
39	 <p>4-carboxy-2,3,5,6-tetrafluoro-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
40	 <p>5-mercapto-2-(phenylthio)-pentanoic acid</p>
41	 <p>3-[1-carboxy-4-mercaptopbutyl]thio]-benzoic acid</p>

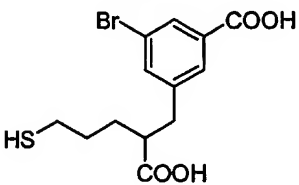
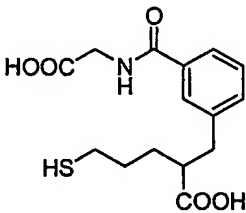
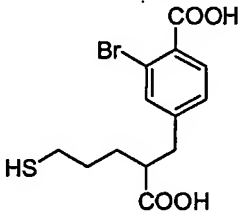
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
42	 <p>alpha-(3-mercaptopropyl)-2-naphthalenepropanoic acid</p>
43	 <p>2-chloro-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
44	 <p>alpha-(3-mercaptopropyl)-3-[[(phenylmethyl) amino] carbonyl]-benzenepropanoic acid</p>

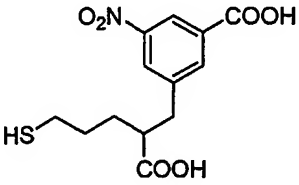
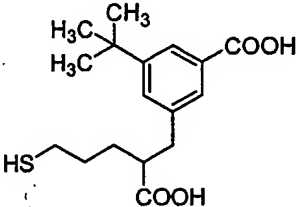
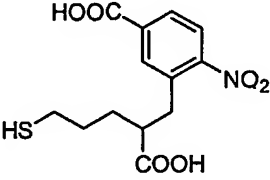
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
45	 <p>3-bromo-5-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
46	 <p>3-[[[(carboxymethyl)amino]carbonyl]-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
47	 <p>3-bromo-4-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

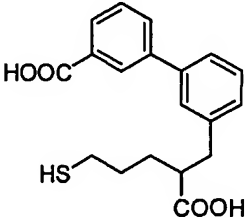
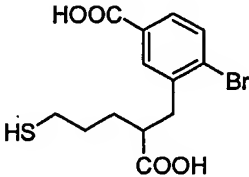
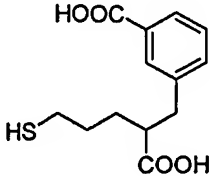
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
48	 <p>3-carboxy-alpha-(3-mercaptopropyl)-5-nitro-benzenepropanoic acid</p>
49	 <p>3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
50	 <p>5-carboxy-alpha-(3-mercaptopropyl)-2-nitro-benzenepropanoic acid</p>

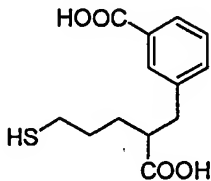
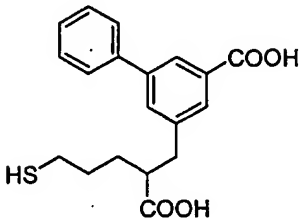
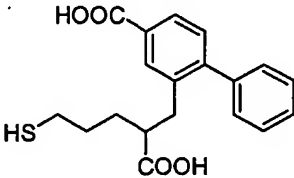
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
51	 <p>3'-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-3-carboxylic acid</p>
52	 <p>2-bromo-5-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
53	 <p>(+)-3-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

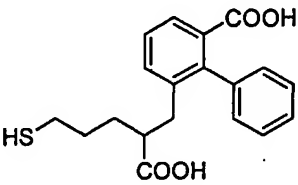
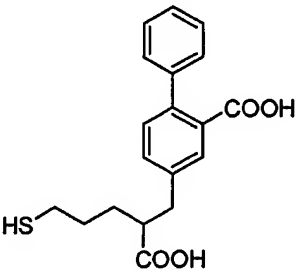
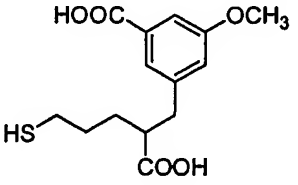
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
54	 <p>(-)-3-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
55	 <p>5-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-3-carboxylic acid</p>
56	 <p>2-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-4-carboxylic acid</p>

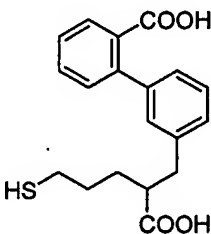
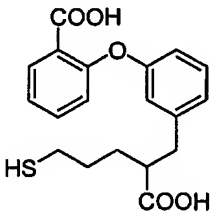
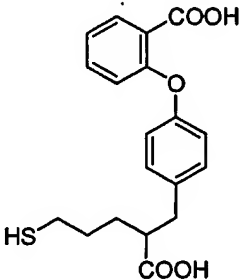
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
57	 <p>6-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-2-carboxylic acid</p>
58	 <p>4-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-2-carboxylic acid</p>
59	 <p>3-carboxy-alpha-(3-mercaptopropyl)-5-methoxybenzenepropanoic acid</p>

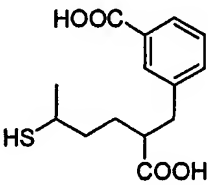
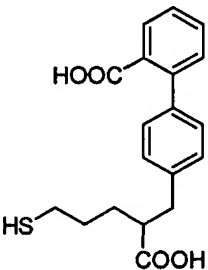
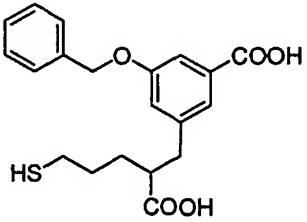
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
60	 <p>3'-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-2-carboxylic acid</p>
61	 <p>3-(2-carboxyphenoxy)-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
62	 <p>4-(2-carboxyphenoxy)-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>

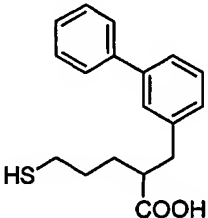
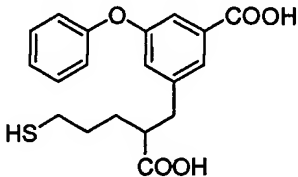
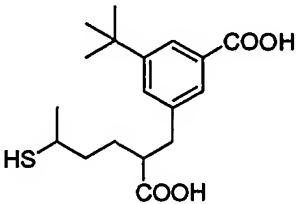
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
63	 <p>3-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
64	 <p>4'-(2-carboxy-5-mercaptopropyl)-[1,1'-biphenyl]-2-carboxylic acid</p>
65	 <p>3-carboxy-alpha-(3-mercaptopropyl)-5-(phenylmethoxy)-benzenepropanoic acid</p>

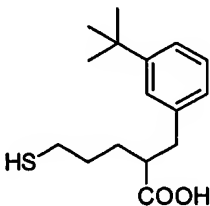
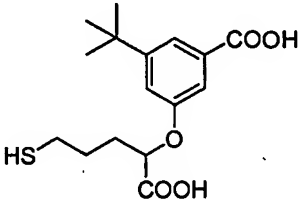
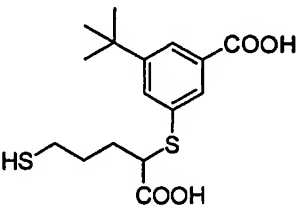
WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
66	 <p>alpha-(3-mercaptopropyl)-3-phenyl-benzenepropanoic acid</p>
67	 <p>3-carboxy-alpha-(3-mercaptopropyl)-5-phenoxy-benzenepropanoic acid</p>
68	 <p>3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptopbutyl)-benzenepropanoic acid</p>

WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
69	 <p>3-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid</p>
70	 <p>3-(1-carboxy-4-mercaptobutoxy)-5-(1,1-dimethylethyl)-benzoic acid</p>
71	 <p>3-[(1-carboxy-4-mercaptobutyl)thio]-5-(1,1-dimethylethyl)-benzoic acid</p>

WO 02/057222

PCT/US02/01205

Compound No.	Structure/Name
72	 3 - [(1-carboxy-4-mercaptobutyl) amino] -5- (1,1- dimethylethyl) -benzoic acid

The inventive compounds possess one or more asymmetric
5 carbon center(s) and are thus capable of existing in the form
of optical isomers as well as in the form of racemic or non-
racemic mixtures of optical isomers. The optical isomers can
be obtained by resolution of the racemic mixtures according
to conventional processes well known in the art, for example
10 by formation of diastereoisomeric salts by treatment with an
optically active acid or base and then separation of the
mixture of diastereoisomers by crystallization followed by
liberation of the optically active bases from these salts.
Examples of useful acids include tartaric, diacetyltartaric,
15 dibenzoyltartaric, ditoluoyltartaric and camphorsulfonic
acids.

WO 02/057222

PCT/US02/01205

A different process for separating optical isomers involves the use of a chiral chromatography column optimally chosen to maximize the separation of the enantiomers. Still another available method involves synthesis of covalent
5 diastereoisomeric molecules, for example, esters, amides, acetals, ketals, and the like, by reacting compounds used in the inventive methods and pharmaceutical compositions with an optically active acid in an activated form, an optically active diol or an optically active isocyanate. The
10 synthesized diastereoisomers can be separated by conventional means, such as chromatography, distillation, crystallization or sublimation, and then hydrolyzed to deliver the enantiomerically pure compound. In some cases, hydrolysis to the parent optically active drug prior to dosing the patient
15 is unnecessary since the compound can behave as a prodrug. The optically active compounds of the invention can likewise be obtained by utilizing optically active starting materials.

It is understood that the inventive compounds encompass optical isomers as well as racemic and non-
20 racemic mixtures.

WO 02/057222

PCT/US02/01205

METHODS OF THE INVENTION

Methods for Inhibiting NAALADase Enzyme Activity

This invention relates to a method for inhibiting NAALADase enzyme activity in an animal or a mammal, comprising administering to said animal or mammal an effective amount of a compound of the invention, as defined above.

Methods for Treating Glutamate Abnormalities

This invention further relates to a method for treating a glutamate abnormality in an animal or a mammal, comprising administering to said animal or mammal an effective amount of a compound of the invention, as defined above.

Glutamate abnormalities to be treated may be selected from the group consisting of compulsive disorder, stroke, ischemia, demyelinating disease, Parkinson's disease, ALS, Huntington's disease, schizophrenia, pain, anxiety, anxiety disorder, memory impairment and glaucoma. Preferably, the compulsive disorder is alcohol, nicotine or cocaine dependence.

Stroke patients often experience a significant temporal delay between the onset of ischemia and the initiation of therapy. Thus, there is a need for neuroprotectants with a long therapeutic window of opportunity. It is expected that the inventive compounds have a therapeutic window of

WO 02/057222

PCT/US02/01205

opportunity of at least 1 hour. Accordingly, when the glutamate abnormality is stroke, the compound of the invention may be administered to said animal or mammal for up to 60 minutes, 120 minutes or more following onset of
5 stroke.

Without being bound to any particular mechanism of action, preferred compounds of the invention are expected to be those that block glutamate release pre-synaptically without interacting with post-synaptic glutamate receptors.
10 Such compounds would be devoid of the behavioral toxicities associated with post-synaptic glutamate antagonists.

Methods for Effecting Neuronal Activities

This invention further relates to a method for effecting a neuronal activity in an animal or a mammal,
15 comprising administering to said animal or mammal an effective amount of a compound of the invention, as defined above.

The neuronal activity that is effected by the inventive method may be stimulation of damaged neurons, promotion of
20 neuronal regeneration, prevention of neurodegeneration or treatment of a neurological disorder.

Examples of neurological disorders that are treatable by the inventive methods include without limitation: trigeminal neuralgia; glossopharyngeal neuralgia; Bell's

WO 02/057222

PCT/US02/01205

Palsy; myasthenia gravis; muscular dystrophy; ALS; progressive muscular atrophy; progressive bulbar inherited muscular atrophy; herniated, ruptured or prolapsed invertebrate disk syndromes; cervical spondylosis; plexus disorders; thoracic outlet destruction syndromes; peripheral neuropathies such as those caused by lead, dapsone, ticks, porphyria, or Guillain-Barré syndrome; diabetic neuropathy; pain; Alzheimer's disease; and Parkinson's disease.

The inventive method is particularly useful for treating a neurological disorder selected from the group consisting of peripheral neuropathy caused by physical injury or disease state, diabetic neuropathy, pain, traumatic brain injury, physical damage to spinal cord, stroke associated with brain damage, demyelinating disease and neurological disorder relating to neurodegeneration.

When the neurological disorder is pain, the compound of the invention is preferably administered in combination with an effective amount of morphine.

Examples of neurological disorders relating to neurodegeneration include Alzheimer's disease, Parkinson's disease, and ALS.

Methods for Treating Prostate Diseases

This invention further relates to a method for treating a prostate disease in an animal or a mammal, comprising

WO 02/057222

PCT/US02/01205

administering to said animal or mammal an effective amount of a compound of the invention, as defined above.

Methods for Treating Cancers

This invention further relates to a method for treating
5 cancer in an animal or a mammal, comprising administering to said animal or mammal an effective amount of a compound of the invention, as defined above.

Preferred cancers to be treated are those in tissues where NAALADase resides, including without limitation the
10 brain, kidney and testis.

Methods for Inhibiting Angiogenesis

This invention further relates to a method for inhibiting angiogenesis in an animal or a mammal, comprising administering to said animal or mammal an effective amount
15 of a compound of the invention, as defined above.

Angiogenesis may be necessary for fertility or metastasis of cancer tumors, or may be related to an angiogenic-dependent disease. Thus, the inventive methods may also be useful for treating an angiogenic-dependent
20 disease including, without limitation, rheumatoid arthritis, cardiovascular diseases, neovascular diseases of the eye, peripheral vascular disorders, dermatologic ulcers and cancerous tumor growth, invasion or metastasis.

WO 02/057222

PCT/US02/01205

Methods for Effecting TGF- β Activity

This invention further relates to a method for effecting a TGF- β activity in an animal or a mammal, comprising administering to said animal or mammal an
5 effective amount of a compound of the invention, as defined above.

Said effecting a TGF- β activity includes increasing, reducing or regulating TGF- β levels, and treating TGF- β abnormalities. Examples of TGF- β abnormalities to be treated
10 include neurodegenerative disorders, extra-cellular matrix formation disorders, cell-growth related diseases, infectious diseases, immune related diseases, epithelial tissue scarring, collagen vascular diseases, fibroproliferative disorders, connective tissue disorders,
15 inflammation, inflammatory diseases, respiratory distress syndrome, infertility and diabetes.

Typical neurodegenerative disorders to be treated include neural tissue damage resulting from ischemia . reperfusion injury, myelination and neurodegeneration.

20 Typical cell-growth related disorders to be treated include those affecting kidney cells, hematopoietic cells, lymphocytes, epithelial cells and endothelial cells.

Typical infectious diseases to be treated include those caused by a macrophage pathogen, particularly a macrophage

WO 02/057222

PCT/US02/01205

pathogen selected from the group consisting of bacteria, yeast, fungi, viruses, protozoa, *Trypanosoma cruzi*, *Histoplasma capsulatum*, *Candida albicans*, *Candida parapsilosis*, *Cryptococcus neoformans*, *Salmonella*,
5 *Pneumocystis*, *Toxoplasma*, *Listeria*, *Mycobacteria*, *Rickettsia* and *Leishmania*. *Mycobacteria* include without limitation *Mycobacterium tuberculosis* and *Mycobacterium leprae*. *Toxoplasma* includes without limitation *Toxoplasma gondii*. *Rickettsia* includes without limitation *R. prowazekii*, *R.*
10 *coronii* and *R. tsutsugamushi*.

Other examples of infectious diseases to be treated include single or multiple cutaneous lesions, mucosal disease, Chagas' disease, acquired immunodeficiency syndrome (AIDS), toxoplasmosis, leishmaniasis, trypanosomiasis,
15 shistosomiasis, cryptosporidiosis, *Mycobacterium avium* infections, *Pneumocystis carinii* pneumonia and leprosy.

Typical immune related diseases to be treated include autoimmune disorders; impaired immune function; and immunosuppression associated with an infectious disease,
20 particularly, trypanosomal infection, viral infection, human immunosuppression virus, human T cell lymphotropic virus (HTLV-1), lymphocytic choriomeningitis virus or hepatitis.

Typical collagen vascular diseases to be treated include progressive systemic sclerosis ("PSS"),
25 polymyositis, scleroderma, dermatomyositis, eosinophilic

WO 02/057222

PCT/US02/01205

fascitis, morphea, Raynaud's syndrome, interstitial pulmonary fibrosis, scleroderma and systemic lupus erythematosus.

Typical fibroproliferative disorders to be treated
5 include diabetic nephropathy, kidney disease, proliferative vitreoretinopathy, liver cirrhosis, biliary fibrosis, and myelofibrosis. Especially preferred kidney diseases include mesangial proliferative glomerulonephritis, crescentic glomerulonephritis, diabetic neuropathy, renal interstitial
10 fibrosis, renal fibrosis in transplant patients receiving cyclosporin, and HIV-associated nephropathy.

Typical connective tissue disorders to be treated include scleroderma, myelofibrosis, and hepatic, intraocular and pulmonary fibrosis.

15 Typical inflammatory diseases to be treated are associated with PSS, polymyositis, scleroderma, dermatomyositis, eosinophilic fascitis, morphea, Raynaud's syndrome, interstitial pulmonary fibrosis, scleroderma, systemic lupus erythematosus, diabetic nephropathy, kidney
20 disease, proliferative vitreoretinopathy, liver cirrhosis, biliary fibrosis, myelofibrosis, mesangial proliferative glomerulonephritis, crescentic glomerulonephritis, diabetic neuropathy, renal interstitial fibrosis, renal fibrosis in transplant patients receiving cyclosporin, or HIV-associated
25 nephropathy.

WO 02/057222

PCT/US02/01205

Without being limited to any particular mechanism of action, preferred compounds of this invention treat inflammatory diseases by regulating TGF- β and/or inhibiting myeloperoxidase.

5 Other uses associated with the inventive compounds' TGF- β regulating properties include:

- stimulating growth of tissue, glands or organs, particularly growth that would enhance milk production or weight gain;
- 10 • stimulating cell proliferation, particularly proliferation of fibroblasts, mesenchymal cells or epithelial cells;
- inhibiting cell growth, particularly of epithelial cells, endothelial cells, T and B lymphocytes and
- 15 thymocytes;
- inhibiting expression of adipose, skeletal muscle and hematopoietic phenotypes, neoplasms, non-cytocidal viral or other pathogenic infections and autoimmune disorders;
- 20 • mediating disease resistance and susceptibility;
- suppressing cellular immune response;
- inhibiting scar tissue formation, preferably in skin or other epithelial tissue that has been damaged by wounds resulting from accidental injury, surgical

WO 02/057222

PCT/US02/01205

operations, trauma-induced lacerations or other trauma, or wounds involving the peritoneum for which the excessive connective tissue formation is abdominal adhesions;

- 5 • increasing the effectiveness of a vaccine, particularly a vaccine for an allergy towards, for example, dust or hayfever; and
- inhibiting polyp formation.

Diagnostic Methods and Kits

10 The inventive compounds are useful for *in vitro* and *in vivo* diagnostic methods for detecting diseases, disorders and conditions where NAALADase levels are altered including, without limitation, neurological disorders, glutamate abnormalities, diabetic neuropathy, pain, compulsive

15 disorders, prostate diseases, cancers, TGF- β abnormalities and glaucoma.

Accordingly, this invention also relates to a method for detecting a disease, disorder or condition where NAALADase levels are altered, comprising:

- 20 (i) contacting a sample of bodily tissue or fluid with a compound of the invention, as defined above, wherein said compound binds to any NAALADase in said sample; and
- (ii) measuring the amount of any NAALADase bound to said sample, wherein the amount of NAALADase is diagnostic
- 25 for said disease, disorder or condition.

WO 02/057222

PCT/US02/01205

Examples of bodily tissues and fluids include, without limitation, prostate tissue, ejaculate, seminal vesicle fluid, prostatic fluid, urine, blood, saliva, tears, sweat, lymph and sputum.

5 The compound may be labeled with a marker using techniques known in the art. Useful markers include, without limitation, enzymatic markers and imaging reagents. Examples of imaging reagents include radiolabels such as ^{131}I , ^{111}In , ^{123}I , ^{99}Tc , ^{32}P , ^{125}I , ^3H and ^{14}C ; fluorescent labels
10 such as fluorescein and rhodamine; and chemiluminescers such as luciferin.

The amount of NAALADase can be measured using techniques known in the art including, without limitation, assays (such as immunometric, calorimetric, densitometric,
15 spectrographic and chromatographic assays) and imaging techniques (such as magnetic resonance spectroscopy ("MRS"), magnetic resonance imaging ("MRI"), single-photon emission computed tomography ("SPECT") and positron emission tomography ("PET")).

20 This invention further relates to a diagnostic kit for detecting a disease, disorder or condition where NAALADase levels are altered, comprising a compound of the invention, as defined above, labeled with a marker. The kit may further comprise buffering agents, agents for reducing
25 background interference, control reagents and/or apparatus

WO 02/057222

PCT/US02/01205

for conducting the test.

This invention further relates to a method for detecting a disease, disorder or condition where NAALADase levels are altered in an animal or a mammal, comprising:

5 (i) labeling a compound of the invention, as defined above, with an imaging reagent;

(ii) administering to said animal or mammal an effective amount of the labeled compound;

(iii) allowing said labeled compound to localize and
10 bind to NAALADase present in said animal or mammal; and

(iv) measuring the amount of NAALADase bound to said labeled compound, wherein the amount of NAALADase is diagnostic for said disease, disorder or condition.

The amount of NAALADase can be measured in vivo using
15 known imaging techniques, as described above.

Incorporation by Reference

The relationship between NAALADase inhibitors and glutamate, and the effectiveness of NAALADase inhibitors in treating and detecting various diseases, disorders and
20 conditions have been discussed in U.S. Patents Nos. 5,672,592, 5,795,877, 5,804,602, 5,824,662, 5,863,536, 5,977,090, 5,981,209, 6,011,021, 6,017,903, 6,025,344, 6,025,345, 6,046,180, 6,228,888 and 6,265,609; International Publications Nos. WO 00/01668 and WO 00/38785; and other

WO 02/057222

PCT/US02/01205

references generally known in the art. The present inventors hereby incorporate by reference, as though set forth herein in full, the entire contents of the aforementioned patents, patent applications and
5 publications, particularly their discussions, figures and data regarding the effectiveness of NAALADase inhibitors in inhibiting angiogenesis, in effecting TGF- β activity, in diagnosing diseases, and in treating ischemia, spinal cord injury, demyelinating diseases, Parkinson's disease, ALS,
10 alcohol dependence, nicotine dependence, cocaine dependence, prostate disease, cancer, diabetic neuropathy, pain, schizophrenia, anxiety, anxiety disorder and memory impairment. The present inventors have discovered that the inventive compounds are effective NAALADase inhibitors.
15 Thus, the inventive compounds are expected to have the same uses as the NAALADase inhibitors disclosed in the patents, patent applications and publications incorporated by reference.

20 **PHARMACEUTICAL COMPOSITIONS OF THE INVENTION**

This invention also relates to a pharmaceutical composition comprising:

- (i) an effective amount of a compound of the invention;
and
- 25 (ii) a pharmaceutically acceptable carrier.

WO 02/057222

PCT/US02/01205

Preferably, the compound of the invention is present in an effective amount for inhibiting NAALADase enzyme activity or angiogenesis, effecting a neuronal activity or TGF- β activity, or treating a glutamate abnormality, compulsive
5 disorder, prostate disease, cancer or glaucoma in an animal or a mammal.

Route of Administration

The inventive compounds and compositions may be administered locally or systemically by any means known to
10 an ordinarily skilled artisan. For example, the inventive compounds and compositions may be administered orally, parenterally, by inhalation spray, topically, rectally, nasally, buccally, vaginally or via an implanted reservoir in dosage formulations containing conventional non-toxic
15 pharmaceutically acceptable carriers, adjuvants and vehicles. The term parenteral as used herein includes subcutaneous, intravenous, intraarterial, intramuscular, intraperitoneal, intrathecal, intraventricular, intrasternal, intracranial or intraosseous injection and
20 infusion techniques. The exact administration protocol will vary depending upon various factors including the age, body weight, general health, sex and diet of the patient; the determination of specific administration procedures would be routine to an ordinarily skilled artisan.

WO 02/057222

PCT/US02/01205

To be effective therapeutically as central nervous system targets, the inventive compounds and compositions should readily penetrate the blood-brain barrier when peripherally administered. Compounds that cannot penetrate
5 the blood-brain barrier can be effectively administered by an intraventricular route or by other methods recognized in the art. See, for example, U.S. Patents Nos. 5,846,565, 5,651,986 and 5,626,862.

Dosage

10 The inventive compounds and compositions may be administered by a single dose, multiple discrete doses or continuous infusion. Pump means, particularly subcutaneous pump means, are preferred for continuous infusion.

Dose levels on the order of about 0.001 to about 10,000
15 mg/kg of the active ingredient compound are useful in the treatment of the above conditions, with preferred levels being about 0.1 to about 1,000 mg/kg, and more preferred levels being about 1 to about 100 mg/kg. The specific dose level for any particular patient will vary depending upon a
20 variety of factors, including the activity and the possible toxicity of the specific compound employed; the age, body weight, general health, sex and diet of the patient; the time of administration; the rate of excretion; drug combination; the severity of the particular disease being

WO 02/057222

PCT/US02/01205

treated; and the form of administration. Typically, in vitro dosage-effect results provide useful guidance on the proper doses for patient administration. Studies in animal models are also helpful. The considerations for determining
5 the proper dose levels are well known in the art.

Administration Regimen

Any administration regimen well known to an ordinarily skilled artisan for regulating the timing and sequence of drug delivery can be used and repeated as necessary to
10 effect treatment. Such regimen may include pretreatment and/or co-administration with additional therapeutic agents.

Co-Administration With Other Treatments

The inventive compounds and compositions may be used alone or in combination with one or more additional agent(s)
15 for simultaneous, separate or sequential use.

The additional agent(s) may be any therapeutic agent(s) known to an ordinarily skilled artisan, including without limitation: one or more compound(s) of the invention; steroids, for example, hydrocortisones such as
20 methylprednisolone; anti-inflammatory or anti-immune drugs, such as methotrexate, azathioprine, cyclophosphamide or cyclosporin A; interferon- β ; antibodies, such as anti-CD4 antibodies; agents which can reduce the risk of a second ischemic event, such as ticlopidine; chemotherapeutic

WO 02/057222

PCT/US02/01205

agents; immunotherapeutic compositions; electromagnetic radiosensitizers; and morphine.

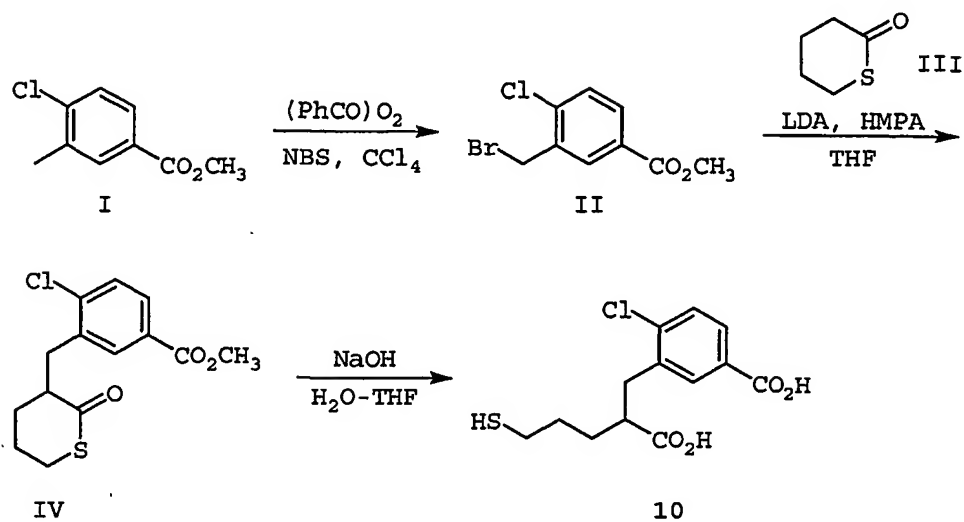
The inventive compounds and compositions can be co-administered with one or more therapeutic agents either
5 together in a single formulation, or separately in individual formulations designed for optimal release rates of their respective active agent. Each formulation may contain from about 0.01% to about 99.99% by weight, preferably from about 3.5% to about 60% by
10 weight, of a compound of this invention, as well as one or more pharmaceutically acceptable carriers.

Preparation of Compounds

The inventive compounds can be readily prepared by standard techniques of organic chemistry, utilizing the
15 general synthetic pathways depicted below in SCHEMES I, II, and III. Precursor compounds are either commercially available or may be prepared by methods known to a person of skill in the art.

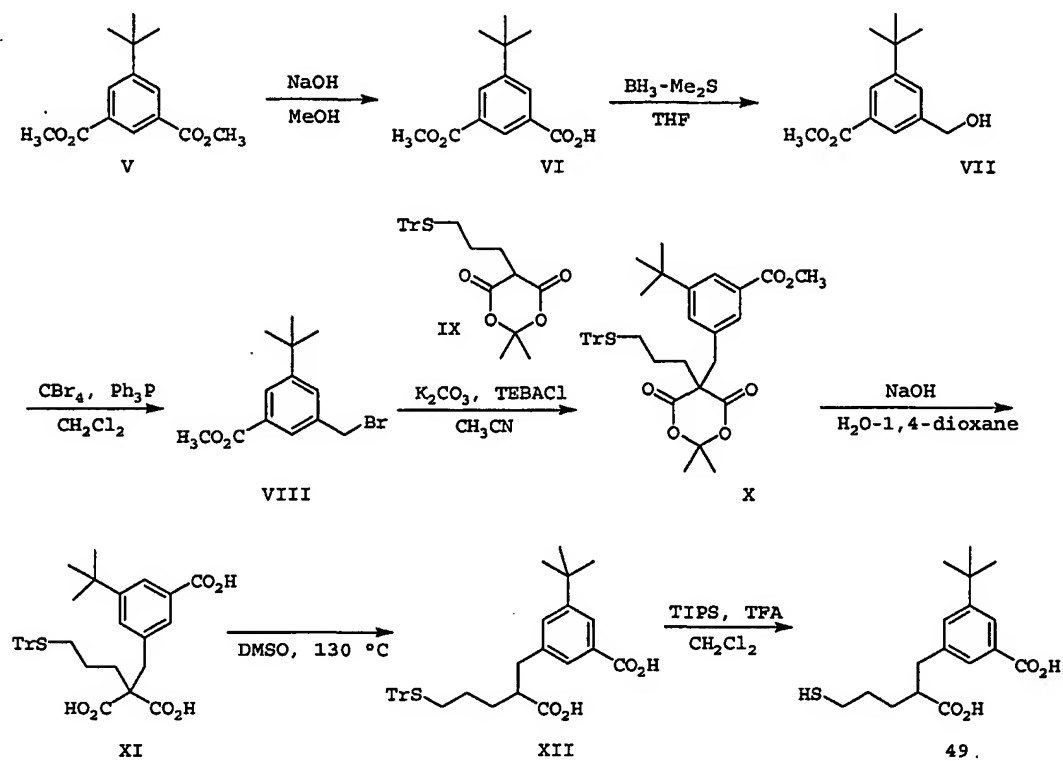
WO 02/057222

PCT/US02/01205

SCHEME I

WO 02/057222

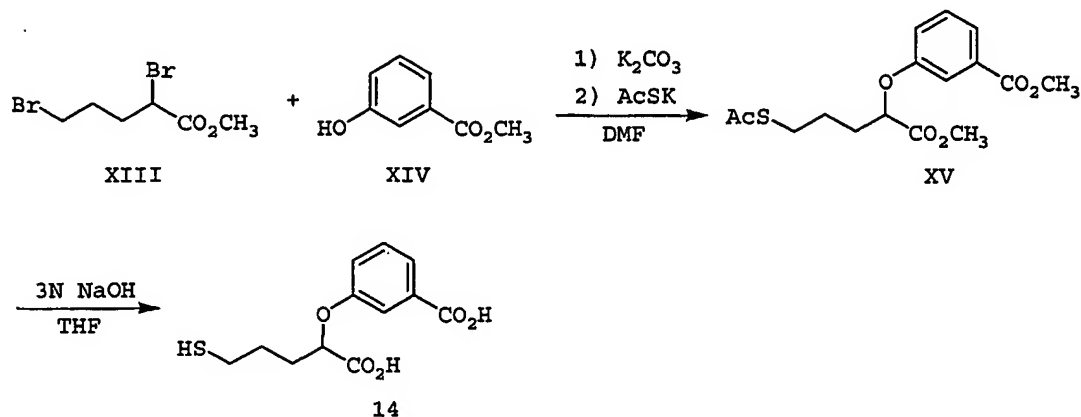
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SCHEME II

WO 02/057222

PCT/US02/01205

SCHEME III



5

EXAMPLES

The following examples are illustrative of this invention and are not intended to be limitations thereon. Unless otherwise indicated, all percentages are based upon 100% by weight of the final composition.

10

EXAMPLE 1

Preparation of 5-carboxy-2-chloro-alpha-(3-mercaptopropyl)-benzenepropanoic acid 10 (Scheme I)

Methyl 3-bromomethyl-4-chlorobenzoate II

15

To a suspension of methyl 4-chloro-3-methylbenzoate I (19.9 g, 108 mmol) and *N*-bromosuccinimide (NBS, 20.2 g, 114 mmol) in carbon tetrachloride (500 mL) was added benzoyl peroxide (1.30 g, 5.4 mmol), and the mixture was stirred at

WO 02/057222

PCT/US02/01205

90 °C overnight. The mixture was then cooled and the white precipitate was removed by filtration. The filtrate was concentrated and the resulting solid was re-crystallized from ethyl acetate to give methyl 3-bromomethy-4-chlorobenzoate **II** (15.0 g, 57 mmol, 53%) as a white solid:
5 ¹H NMR (CDCl₃) δ 3.95 (s, 3H), 4.63 (s, 2H), 7.49 (d, *J* = 8.3 Hz, 1H), 7.94 (dd, *J* = 2.1, 8.3 Hz, 1H), 8.15 (d, *J* = 2.1 Hz, 1H).

10 3-(2-Chloro-5-methoxycarbonylbenzyl)-tetrahydrothiopyrane-2-one IV

To a solution of lithium diisopropylamide (2.0 M solution, 3.3 mL, 6.6 mmol) in THF (25 mL) was added tetrahydrothiopyran-2-one **III** (0.731 g, 6.3 mmol) at -40 °C, and the mixture was stirred at -40 °C for 45 minutes. A
15 solution of methyl 3-bromomethy-4-chlorobenzoate **II** (1.67 g, 6.3 mmol) in THF (10 mL) was then dropwise added to the mixture at -40 °C. Subsequently, hexamethylphosphoramide (0.20 g, 1.4 mmol) was added to the mixture at -40 °C, and the reaction mixture was stirred at -40 °C for 4 hours. A
20 saturated ammonium chloride solution (30 mL) was added to the reaction mixture, and the organic solvent was removed under reduced pressure. The mixture was then partitioned between ether (150 mL) and H₂O (150 mL). The organic layer was washed with brine, dried over MgSO₄, and concentrated.

WO 02/057222

PCT/US02/01205

The crude material was chromatographed on silica gel using EtOAc/hexanes to afford 3-(2-chloro-5-methoxycarbonylbenzyl)-tetrahydrothio-pyrane-2-one IV (0.60 g, 2.0 mmol, 32%) as a white solid: ^1H NMR (CDCl_3) δ 1.65-1.75 (m, 1H), 1.90-2.05 (m, 2H), 2.05-2.15 (m, 2H), 2.74 (dd, $J = 9.4, 13.9$ Hz, 1H), 2.85-3.00 (m, 1H), 3.10-3.20 (m, 2H), 3.58 (dd, $J = 4.7, 13.9$ Hz, 1H), 3.92 (s, 3H), 7.44 (d, $J = 8.3$ Hz, 1H), 7.85 (dd, $J = 8.3, 2.1$ Hz, 1H), 7.91 (d, $J = 2.1$ Hz, 1H).

10 5-Carboxy-2-chloro-alpha-(3-mercaptopropyl)
benzenepropanoic acid 10

A solution of 3-(2-Chloro-5-methoxycarbonylbenzyl)-tetrahydrothiopyrane-2-one IV (9.26 g, 31.0 mmol) in THF (70 mL) was purged for 15 minutes with nitrogen. A degassed aqueous sodium hydroxide solution (2.2 M, 70 mL, 154 mmol) was added to the solution and the mixture was stirred at room temperature under nitrogen overnight. The reaction mixture was washed with ether, acidified by 3N HCl at 0 °C, and extracted with ether. The extract was dried over MgSO_4 and concentrated to afford 5-carboxy-2-chloro-alpha-(3-mercaptopropyl) benzenepropanoic acid 10 (8.42 g, 27.8 mmol, 90%) as a white solid: ^1H NMR (CD_3OD) δ 1.50-1.80 (m, 4H), 2.35-2.50 (m, 2H), 2.65-2.75 (m, 1H), 2.91 (dd, $J = 6.2, 13.8$ Hz, 1H), 2.96 (dd, $J = 8.8, 13.8$ Hz, 1 H), 7.39 (d, $J =$

WO 02/057222

PCT/US02/01205

8.3 Hz, 1H), 7.76 (dd, $J = 2.0$, 8.3 Hz, 1H), 7.86 (d, $J = 2.0$ Hz, 1H); ^{13}C NMR (CD_3OD) δ 25.1, 32.5, 33.2, 37.4, 46.8, 130.8, 131.2, 134.0, 139.1, 140.5, 169.2, 178.9. Anal. Calcd for $\text{C}_{13}\text{H}_{15}\text{ClO}_4\text{S}$: C, 51.57; H, 4.99; S, 10.59; Cl, 11.71. Found: C, 51.59; H, 4.94; S, 10.43; Cl, 11.80.

EXAMPLE 2

Preparation of 3-carboxy-5-(1,1-dimethylethyl)- α -(3-mercaptopropyl)-benzenepropanoic acid 49 (Scheme II)

10 Methyl 5-tert-butylhydrogenisophthalate VI

To a solution of dimethyl 5-tert-butylisophthalate V (23.0 g, 92 mmol) in methanol (150 mL) was added a solution of sodium hydroxide (3.68 g, 92 mmol) in H_2O (10 mL) at 25 °C, and the mixture was stirred at 25 °C for 3 hours. The organic solvent was removed under reduced pressure and the residual solid was suspended in an aqueous sulfuric acid solution (1.0 M). The suspension was filtered and the precipitate was washed with H_2O , dried under vacuum, and crystallized from hexanes/ethyl acetate to afford methyl 5-tert-butylhydrogenisophthalate VI (16.3 g, 69.0 mmol, 75%) as a white solid: ^1H NMR (CDCl_3) δ 1.45 (s, 9H), 3.9 (s, 3H), 8.5 (s, 1H), 8.7 (s, 1H), 8.8 (s, 1H); ^{13}C NMR (CDCl_3) δ 31.3 (3C), 35.2, 52.5, 128.8, 129.7, 130.7, 131.1, 131.6, 132.0, 166.7, 171.5.

WO 02/057222

PCT/US02/01205

Methyl 3-tert-butyl-5-hydroxymethylbenzoate VII

Borane-dimethyl sulfide complex (7.23 mL, 76.2 mmol) was slowly added to a solution of methyl 5-tert-butylhydrogenisophthalate VI (12.0 g, 50.8 mmol) in THF (100 mL) over the period of 20 minutes at room temperature. The mixture was stirred for 1.5 hours at room temperature and then refluxed for 1 additional hour. The reaction mixture was then cooled and the unreacted borane was decomposed with methanol (10 mL). The solvents were removed under reduced pressure and the residue was dissolved in ethyl acetate. The organic solution was washed with a saturated NaHCO₃ solution, dried over MgSO₄, and purified by a silica gel column chromatography (hexane/ethyl acetate) to afford methyl 3-tert-butyl-5-hydroxymethylbenzoate VII (10.0 g, 45.0 mmol, 90%) as a white solid: ¹H NMR (CDCl₃) δ 1.45 (s, 9H), 3.9 (s, 3H), 4.7 (s, 2H), 7.6 (s, 1H), 7.8 (s, 1H), 8.0 (s, 1H); ¹³C NMR (CDCl₃) δ 31.4 (3C), 35.0, 52.3, 65.3, 125.5, 126.1, 128.8, 130.3, 141.0, 152.1, 167.5.

Methyl 3-bromomethyl-5-tert-butylbenzoate VIII

To a solution of methyl 3-tert-butyl-5-hydroxymethylbenzoate VII (9.50 g, 42.7 mmol) and carbon tetrabromide (17.25 g, 52.0 mmol) in dichloromethane (50 mL) was slowly added triphenylphosphine (13.6 g, 52.0 mmol) over the period of 20 minutes, and the mixture was stirred at

WO 02/057222

PCT/US02/01205

room temperature for 25 minutes. The reaction mixture was concentrated under reduced pressure and the residue was suspended in ethyl acetate. The precipitate was removed by filtration and the filtrate was concentrated. The crude
5 material was purified by a silica gel chromatography (hexanes/ethyl acetate, 4:1), and the product was recrystallized from ethyl acetate/hexanes to afford methyl 3-bromomethyl-5-tert-butylbenzoate VIII (12.0 g, 42.1 mmol, 99%) as a white solid: ¹H NMR (CDCl₃) δ 1.45 (s, 9H), 3.7 (s, 3H), 4.4 (s, 2H), 7.6 (s, 1H), 7.8 (s, 1H), 8.0 (s, 1H); ¹³C
10 NMR (CDCl₃) δ 31.3 (3C), 33.2, 36.0, 52.3, 126.9, 127.5, 130.6, 130.7, 137.9, 152.4, 167.0.

5-(3-tert-butyl-5-methoxycarbonyl-benzyl)-2,2-dimethyl-5-[3-
[(triphenylmethyl)thio]propyl]-[1,3]dioxane-4,6-dione X

15 A solution of methyl 3-bromomethyl-5-tert-butylbenzoate (10.3 g, 36.1 mmol), 2,2-dimethyl-5-[3-[(triphenylmethyl)thio]propyl]-[1,3]dioxane-4,6-dione IX (13.8 g, 30.0 mmol), and benzyltriethylammonium chloride (6.38 g, 30 mmol) in acetonitrile (90 mL) was added potassium carbonate (4.35 g,
20 30 mmol) at 25 °C, and the reaction mixture was stirred at 60 °C overnight (the synthesis of compound IX was previously described in International Publication No. WO 00/01668). The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and a 10%

WO 02/057222

PCT/US02/01205

aqueous KHSO₄ solution. The organic layer was dried over MgSO₄, concentrated. The crude material was recrystallized from ethyl acetate/hexane mixture to afford 5-(3-tert-butyl-5-methoxycarbonyl-benzyl)-2,2-dimethyl-5-[3-[(triphenyl-
5 methyl)thio]propyl]-[1,3]dioxane-4,6-dione **X** (14.0 g, 79%) as a white solid: ¹H NMR (CDCl₃) δ 0.7 (s, 3H), 1.3 (s, 9H), 1.2-1.3 (m, 2H), 1.5 (s, 3H), 2.0 (m, 2H), 2.2 (m, 2H), 3.3 (s, 2H), 3.8 (s, 3H), 7.2-7.4 (m, 16H), 7.6 (s, 1H), 7.8 (s, 1H); ¹³C NMR (CDCl₃) δ 24.8, 29.1, 29.4, 31.2, 31.4, 34.9,
10 40.3, 43.7, 52.3, 57.3, 66.8, 105.8, 126.0, 126.8, 128.0, 128.5, 129.6, 130.5, 132.3, 135.3, 144.8, 152.4, 167.1, 168.5.

2-(3-tert-Butyl-5-methoxycarbonyl-benzyl)-2-[3-[(triphenylmethyl)thio]propyl]-malonic acid **XI**

15 To a solution of 5-(3-tert-butyl-5-methoxycarbonyl-benzyl)-2,2-dimethyl-5-[3-[(triphenylmethyl)thio]propyl]-[1,3]dioxane-4,6-dione **X** (11 g, 16.5 mmol) in 1,4-dioxane (15 ml) was added a solution of sodium hydroxide (4.63 g, 115.5 mmol) in H₂O (15 mL) at 25 °C, and the mixture was
20 stirred at 100 °C for 1 hour. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and a 10% aqueous KHSO₄ solution. The organic layer was dried over MgSO₄, concentrated. The crude material was recrystallized from ethyl acetate/hexane mixture to

WO 02/057222

PCT/US02/01205

afford 2-(3-*tert*-butyl-5-methoxycarbonyl-benzyl)-2-[3-
[(triphenyl-methyl)thio]propyl]malonic acid **XI** (9.0 g, 90%)
as a white solid: ^1H NMR (CD_3OD) δ 1.4 (s, 9H), 1.4 (m, 2H),
1.6 (m, 2H), 2.1 (t, J = 8.0 Hz, 2H), 3.2 (s, 2H), 7.1-7.4
5 (m, 16H), 7.7 (s, 1H), 7.9 (s, 1H); ^{13}C NMR (CD_3OD) δ 24.8,
31.8 (3C), 32.4, 33.3, 35.6, 39.0, 59.5, 67.7, 126.2, 127.7,
128.9, 129.6, 130.7, 131.5, 132.9, 137.8, 146.2, 152.6,
170.1, 174.5.

2-(3-*tert*-Butyl-5-methoxycarbonyl-benzyl)-5-
10 [(triphenylmethyl)thio]pentanoic acid **XII**

A solution of 2-(3-*tert*-butyl-5-methoxycarbonyl-benzyl)-2-[3-[(triphenylmethyl)thio]propyl]-malonic acid **XI**
(6.71 g, 11 mmol) in DMSO (10 ml) was stirred at 130 °C for
1.5 hours. The solvent was removed under reduced pressure
15 and water was added to the residual oil. The precipitate
was filtered off, washed with water, and dried under vacuum
to afford 2-(3-*tert*-butyl-5-methoxycarbonyl-benzyl)-5-
[(triphenylmethyl)thio]-pentanoic acid **XII** (5.86 g, 10.3
mmol, 94%) as a white solid: ^1H NMR (CD_3OD) δ 1.3 (s, 9H),
20 1.3-1.5 (m, 4H), 2.1 (m, 2H), 2.4 (m, 1H), 2.7 (m, 1H), 2.8
(m, 1H), 7.1-7.4 (m, 16H), 7.7 (s, 1H), 7.9 (s, 1H); ^{13}C NMR
(CD_3OD) δ 27.4, 31.7 (3C), 32.3, 32.7, 35.6, 39.2, 48.4,
67.7, 125.7, 127.7, 128.6, 128.9, 130.8, 131.6, 132.0,
140.8, 146.3, 152.7, 170.3, 178.8.

WO 02/057222

PCT/US02/01205

3-Carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid 49

To a solution of 2-(3-tert-butyl-5-methoxycarbonyl-benzyl)-5-[(triphenylmethyl)thio]pentanoic acid **XII** (5.5 g, 9.7 mmol) in dichloromethane (30 mL) were added triisopropylsilane (2.4 mL, 11.6 mmol) and trifluoroacetic acid (10 mL), and the mixture was stirred at room temperature for 10 minutes. The solvent was removed under reduced pressure and the crude material was purified by silica gel chromatography (1% AcOH in Hexanes/EtOAc, 4:1) to afford 3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid **49** (1.7 g, 5.3 mmol, 55%) as a white solid: ¹H NMR (CD₃OD) δ 1.3 (s, 9H), 1.5-1.8 (m, 4H), 2.4 (m, 2H), 2.6-2.7 (m, 1H), 2.8-2.9 (m, 1H), 2.9-3.0 (m, 1H), 7.5 (s, 1H), 7.7 (s, 1H), 7.8 (s, 1H); ¹³C NMR (CD₃OD) δ 24.8, 31.7 (3C), 31.9, 32.9, 35.6, 39.5, 48.6, 125.7, 128.5, 131.6, 132.0, 140.9, 152.8, 170.3, 179.0. Anal. Calcd for C₁₇H₂₄O₄S: C, 62.93; H, 7.46; S, 9.88. Found: C, 63.02; H, 7.36; S, 9.82.

20

EXAMPLE 3

Preparation of 3-(1-Carboxy-4-mercaptoputoxy)-benzoic Acid

14 (Scheme III)

WO 02/057222

PCT/US02/01205

Methyl 3-(4-acetylthio-1-methoxycarbonyl-butoxy)-benzoate XV

To a solution of methyl 2,5-dibromopentanoate XIII (22.00 g, 80.3 mmol) and methyl 3-hydroxybenzoate XIV (10.18 g, 66.9 mmol) in DMF (80 mL) was added K₂CO₃ (12.94 g, 93.7 mmol) at room temperature. The mixture was stirred at room temperature under N₂ for 12 hours, then heated at 70 °C for 1 h. Potassium thioacetate (22.93 g, 200.8 mmol) was added to the mixture, which was heated at 70 °C for 2 hours. The mixture was allowed to cool to room temperature and was diluted with EtOAc (1000 mL). The mixture was washed with H₂O (3 X 300 mL) and brine (2 X 300 mL). The organic layer was dried over MgSO₄, filtered and concentrated. The crude product was purified by flash chromatography (gradient elution: 10% to 20% EtOAc/hexanes) to afford methyl 3-(4-acetylthio-1-methoxycarbonyl-butoxy)-benzoate XV (8.40 g, 24.7 mmol, 37%) as a yellow oil: R_f 0.26 (hexanes/EtOAc, 4:1): ¹H NMR (CDCl₃) δ 1.73-1.88 (m, 2H), 2.01-2.08 (m, 2H), 2.32 (s, 3H), 2.93 (t, J = 7.2 Hz, 2H), 3.75 (s, 3H), 3.89 (s, 3H), 4.69 (t, J = 6.2 Hz, 1H), 7.07 (dm, J = 8.0 Hz, 1H), 7.33 (t, J = 7.9 Hz, 1H), 7.50 (m, 1H), 7.65 (dm, J = 7.7 Hz, 1H); ¹³C NMR (CDCl₃) δ 25.3, 28.3, 30.5, 31.4, 52.1, 52.2, 75.8, 115.4, 120.0, 122.8, 129.5, 131.4, 157.5, 166.4, 171.3, 195.4.

WO 02/057222

PCT/US02/01205

3-(1-Carboxy-4-mercaptobutoxy)-benzoic acid 14

A solution of methyl 3-(4-acetylthio-1-methoxy-carbonylbutoxy)benzoate XV (8.00 g, 23.5 mmol) in THF (60 mL) was deoxygenated by bubbling N₂ through the solution for 1 hour. To the solution was added deoxygenated 3 N NaOH (47 mL, 141 mmol) and the mixture was stirred for 24 hours at room temperature under N₂. The mixture was acidified with 1 N HCl and extracted with EtOAc (3 X 300 mL). The organic extracts were washed with water (300 mL) and brine (300 mL), dried over MgSO₄, filtered, and concentrated. The residual oil was dissolved in ether and the solution was concentrated to afford 3-(1-carboxy-4-mercaptobutoxy)-benzoic acid 14 (4.40 g, 16.3 mmol, 69%) as a white solid: ¹H NMR (CDCl₃) δ 1.40 (t, J = 7.9 Hz, 1H), 1.83-1.99 (m, 2H), 2.11-2.22 (m, 2H), 2.63 (m, 2H), 4.76 (dd, J = 7.3, 5.0 Hz, 1H), 7.23 (m, 1H), 7.38 (t, J = 7.8 Hz, 1H), 7.49 (m, 1H), 7.72 (d, J = 7.7 Hz, 1H); ¹³C NMR (CDCl₃) δ 24.1, 29.6, 31.2, 75.5, 114.8, 122.1, 123.9, 129.9, 130.5, 157.6, 171.8, 177.1. Anal. Calcd for C₁₂H₁₄O₅S: C, 53.32; H, 5.22; S, 11.86. Found: C, 53.04; H, 5.38; S, 11.58.

WO 02/057222

PCT/US02/01205

EXAMPLE 4

Preparation of (+)-3-carboxy- α -(3-mercaptopropyl)-
benzenepropanoic acid 53 and (-)-3-carboxy- α -(3-
mercaptopropyl)-benzenepropanoic acid 54

5 A solution of racemic 3-carboxy- α -(3-mercaptopropyl)-
benzenepropanoic acid (2.70 g, 10.1 mmol) was divided into
multiple samples of equal volume, and each of them was
passed through a CHIRAPAK AD column (250 mm x 21 mm id)
using carbon dioxide/methanol (77/23, v/v) as eluent at a
10 flow rate of 25 mL/min, at 25 °C. The first eluting peak
(detected by UV at 290 nm) from each run was combined and
concentrated to afford (+)-3-carboxy- α -(3-mercaptopropyl)-
benzenepropanoic acid 53 (1.02 g, 38%) as a colorless oil:
[α]²⁵_D = +15.5 (c = 1.1, CH₃CN). (-)-3-carboxy- α -(3-
15 mercaptopropyl)-benzenepropanoic acid 54 (1.08 g, 40%) was
obtained likewise from the second peaks as a colorless oil:
[α]²⁵_D = -13.4 (c = 1.1, CH₃CN).

EXAMPLE 5

20 In Vitro Inhibition of NAALADase Activity

Various compounds of this invention were tested for *in vitro* inhibition of NAALADase activity, and the results are provided below in TABLE II.

WO 02/057222

PCT/US02/01205

TABLE IIIn Vitro Inhibition of NAALADase Activity

Compound No.	IC ₅₀
1	4000
2	2270
3	2140
4	1000
5	17
6	59
7	211
8	450
9	2.55
10	2.09
11	12
12	316
13	3950
14	16.3
15	555
16	16,100
17	566
18	308
19	846
20	64

WO 02/057222

PCT/US02/01205

Compound No.	IC ₅₀
21	82
22	229
23	2900
24	27700
25	29.8
26	2200
27	287
28	809
29	4600
30	192
31	1200
32	175
33	118
34	400
35	6.33
36	26
37	316
38	1700
39	660
40	297
41	24
42	1130
43	1350

WO 02/057222

PCT/US02/01205

Compound No.	IC ₅₀
44	1130
45	2.5
46	286
47	146
48	3
49	0.05
50	8.25
51	1.83
52	3.33
53	7
54	33.3
56	19
57	70
58	18
59	13
60	184
61	49
62	3590
63	30
64	87
66	181
67	5
68	1

WO 02/057222

PCT/US02/01205

Protocol for Assaying In Vitro Inhibition of NAALADaseActivity

The following were combined in assay tubes: 100 μ L of 10 mM CoCl_2 , 250 μ L of 200 mM Tris chloride, 100 μ L tissue, 5 100 μ L of 10 mM NAALADase inhibitor in Bakers H_2O , and Bakers H_2O to make a total volume of 950 μ L. Each assay tube was then incubated for 10 minutes in a 37EC water bath. 50 μ L of 3-H-NAAG was then added to each assay tube and incubated for an additional 15 minutes in a 37EC water bath. The assay 10 was stopped by adding 1.0 ml of 0.1 M sodium phosphate.

Glutamate released by the action of the NAALADase enzyme was separated from the assay solution using an anion exchange resin. The resin was equilibrated to 25EC, 2.0 ml of the resin was added to a Pasteur pipette pre-loaded with a single 15 glass bead, and each column was washed twice with distilled H_2O . A column was placed over a scintillation vial and 200 μ L of an assay sample was loaded onto the column. After draining, glutamate was eluted using two 1.0 ml washes of 1 M formic acid. After addition of 10 ml of scintillation 20 cocktail, each sample was counted for 2 minutes on a scintillation counter.

EXAMPLE 6In Vitro Assay on Ischemia

WO 02/057222

PCT/US02/01205

To examine the *in vitro* effect of the inventive compounds on ischemia, cortical cell cultures were treated with various compounds of this invention during an ischemic insult utilizing potassium cyanide and 2-deoxyglucose, and
5 for one hour thereafter. For a description of the experimental method used, see Vornov et al., *J. Neurochem.*, Vol. 65, No. 4, pp. 1681-1691 (1995). The results are provided below in TABLE III. Neuroprotective effect is expressed as EC₅₀, the concentration of the compound, which is
10 required to cause a 50% reduction in glutamate toxicity following an ischemic insult.

TABLE III

Compound No.	EC ₅₀
5	6.5
6	17.8
7	1060
8	133
9	104
10	7.7
11	15.4
12	188
13	10,000

WO 02/057222

PCT/US02/01205

Compound No.	EC ₅₀
14	16
15	1,000
16	267
17	1400
18	230
20	39.3
21	11.6
23	21
26	1800
27	155
28	48
30	399
31	31
32	7
33	110
34	346
35	23
36	74.9
37	215
38	762
39	290
40	452
41	409

WO 02/057222

PCT/US02/01205

Compound No.	EC ₅₀
42	265
43	452
45	2
46	544
47	119
48	2.4
50	26
55	1
56	11
57	21
58	16

EXAMPLE 7

Effect of NAALADase Inhibition on TGF- β in In Vitro Ischemia

5

Model

A NAALADase inhibitor, Compound C, was added to ischemia cell cultures to determine its effect on TGF- β levels during stroke. The experimental data, set forth in FIGS. 1 and 2, show increased concentrations of TGF- β 1 (FIG. 1) and TGF- β 2 (FIG. 2) in ischemic cell cultures treated with Compound C. The results indicate that NAALADase inhibition promotes the release of endogenous TGF- β 's from

WO 02/057222

PCT/US02/01205

glial cells, which in turn provides neuroprotection for neighboring neurons.

TGF- β neutralizing antibodies were then added to the ischemic cell cultures. FIG. 3 shows that the TGF- β neutralizing antibodies blocked the neuroprotective effect of Compound C in the *in vitro* ischemia model. By contrast, FIG. 4 shows that the addition of another growth factor antibody, FGF antibody, did not block the neuroprotective effect of Compound C. The results indicate that NAALADase inhibition specifically affects TGF- β levels during stroke.

EXAMPLE 8

Effect of NAALADase Inhibition on TGF- β in *In Vivo* Ischemia

Model

The effect of TGF- β neutralizing antibodies on the neuroprotective effect of Compound C was also studied in rats following MCAO. FIG. 6 shows that treatment of MCAO rats with Compound C caused a significant rise in TGF- β 1 levels during both occlusion and reperfusion, as assessed by microdialysis. The results indicate that NAALADase inhibition provides neuroprotection, at least in part, by regulating endogenous TGF- β 's.

Additionally, FIG. 5 shows that TGF- β neutralizing antibodies significantly attenuated the neuroprotective

WO 02/057222

PCT/US02/01205

effect of Compound C *in vivo*. One of ordinary skill in the art can appreciate that the regulation of TGF- β 's by NAALADase inhibitors may have implications not only in stroke, but also in other diseases, disorders and conditions including, without limitation, neurological diseases, psychiatric diseases, demyelinating diseases, prostate cancer, inflammation, diabetes and angiogenesis.

EXAMPLE 9

10 In Vivo Assay of NAALADase Inhibitors on Neuropathic Pain in STZ Model

Male Sprague-Dawley rats (200-225 g) were rendered diabetic by intravenous administration of streptozotocin ("STZ", 70 mg/kg in phosphate buffered saline). Diabetic animals were divided into five groups: one group receiving Compound A (10 mg/kg or 1 mg/kg), Compound D (10 mg/kg or 1 mg/kg) or vehicle. Another group of animals (non-STZ treated) served as non-diabetic controls. Drug/vehicle treatment was started in diabetic animals 45 days post-STZ administration. STZ-induced diabetic rats were tested for sensitivity to a heat source as soon as blood glucose levels rose to 320 mg/dl or above (30 days post STZ). The rats were then acclimated to a Hargreaves apparatus and thermal nociception was monitored using an infrared heat source directed into the dorsal surface of the hindpaw, and the time

WO 02/057222

PCT/US02/01205

taken for the animal to remove its paw noted to the nearest 0.1 seconds (see Hargreaves et al., supra, for detailed experimental method). The intensity of the beam source was adjusted such that the mean latency for control animals (non-STZ treated) was approximately 10 seconds. Each animal was tested 8 times and the mean difference score (between mean non-diabetic control latency and mean diabetic latency) are graphically presented in FIGS. 7A and 7B. Diabetic rats displayed a hyperalgesia (shorter response latency) compared to non-diabetic controls, starting 30 days post STZ treatment and progressively worsening in vehicle treated rats. This hyperalgesic response was completely reversed in diabetic rats receiving treatment with Compound D or A (10 mg/kg i.p. daily). Thus, the results show that NAALADase inhibition attenuates neuropathic pain.

EXAMPLE 10

In Vivo Assay of NAALADase Inhibitors on Neuropathic Pain in

CCI Model

Sciatic nerve ligation, consisting of 4 ligatures tied loosely around the sciatic nerve at 1 mm intervals proximal to the nerve trifurcation, was performed on rats. Following sciatic nerve ligation, the rats exhibited a thermal hyperalgesia and allodynia. The rats were habituated to a Hargreaves apparatus. An infrared

WO 02/057222

PCT/US02/01205

heat source was directed onto the dorsal surface of each rat's hindpaws and the time taken for the rat to withdraw its paws was noted. The difference in scores between the latency of the response for the paw on the operated side
5 versus the paw on the unoperated control side was determined.

Compound 49

The rats were treated with either Compound 49 (10, 1 or 0.1 mg/kg) or a vehicle for 15 days after sciatic nerve
10 ligation. Thermal pain responses were measured at days 0, 1, 5, 8, 11 and 15. The differences in scores for the rats treated with a vehicle and the rats treated with Compound 49 are graphically presented in FIGS. 13-15. The results show that treatment with Compound 49 normalized the difference in
15 scores between the operated and unoperated paws compared to the continued hyperalgesic vehicle-treated rats. The time taken for the rats to withdraw its paw on the unoperated (sham) side are graphically presented in FIG. 16. The rats exhibited approximately equal withdrawal latencies
20 on the sham side regardless of treatment.

Compound 5

The rats were treated with either Compound 5 (50, 30, 10, 3, 1 or 0.3 mg/kg) or a vehicle for 12 (or 15) days after sciatic nerve ligation. Thermal pain responses were measured

WO 02/057222

PCT/US02/01205

at days 0, 1, 5, 8 and 12 (and 15). The differences in scores for the rats treated with a vehicle and the rats treated with Compound 5 are graphically presented in FIGS. 17-22. The results show that treatment with Compound 5 normalized the difference in scores between the operated and unoperated paws compared to the continued hyperalgesic vehicle-treated rats. The time taken for the rats to withdraw its paw on the unoperated (sham) side are graphically presented in FIG. 23. The rats exhibited approximately equal withdrawal latencies on the sham side regardless of treatment.

Compound C

The rats received either Compound C (50 mg/kg i.p. daily) or a vehicle starting 10 days post surgery. Treatment with Compound C dramatically normalized the difference scores between the two paws compared to the continued hyperalgesic vehicle-treated controls. Normal (unoperated) rats had approximately equal latencies for both paws. This effect was significant starting at 11 days of drug treatment and persisted through to the end of the study (for 21 days of daily dosing). The difference scores are graphically presented in FIG. 8. The results show that NAALADase inhibition attenuates CCI-associated hyperalgesia.

WO 02/057222

PCT/US02/01205

EXAMPLE 11In Vivo Assay of NAALADase Inhibitors on Progression of
Neuropathic Pain in BB/W Models

Compounds D and A

5 Male BB/W rats (BRI, Mass) spontaneously develop a cell mediated autoimmune destruction of pancreatic B cells, resulting in onset of insulin-dependent (Type I) diabetes (Guberski 1994). These rats have been characterized and shown to demonstrate neuropathies with accompanying neural

10 deficits such as fiber loss and degeneration, changes which are correlative with those seen in peripheral nerve of human diabetic patients (Yagihasi 1997). This renders them valuable for experimental trials of new compounds for future treatments of this major disorder. In the present study,

15 Compound D and Compound A were examined for their ability to alter the progression of diabetic neuropathy. The rats received daily injection of Compound D or Compound A (10 mg/kg i.p.) or vehicle, starting at the onset of diabetes (hyperglycemia) and up to 6 months thereafter. Another group

20 of non-diabetic rats also receiving vehicle were tested. All animals were continuously monitored for body weight, urine volume, blood sugar and glycated haemoglobin. In the first month of the study, all animals were tested for thermal nociception in a Hargreaves apparatus, weekly. After the

25 first month this was done biweekly and then monthly. The

WO 02/057222

PCT/US02/01205

testing consists of directing an infrared heat source onto the dorsal surface of the rat hindpaw and noting the time taken for the animal to remove its paw (see Hargreaves et al., supra, for a description of the experimental method).

5 Each animal was tested 8 times and the mean withdrawal latency noted.

The results are graphically presented in FIG. 11. The results show that diabetic rats displayed a hyperalgesia (shorter response latency) compared to non-diabetic controls.

10 Diabetic drug-treated rats (both Compound D and Compound A) displayed longer withdrawal latencies than diabetic vehicle-treated rats, starting after 4 weeks of treatment and persisting through the six months of treatment.

Nerve conduction velocity was also measured every two

15 weeks through the first eight weeks of treatment and every month thereafter through to the six months of treatment (see De Koning et al., *Peptides*, Vol. 8, No. 3, pp. 415-22 (1987) for a description of the experimental method). The results are graphically presented in FIG. 12. Diabetic animals

20 generally showed a reduction in nerve conduction velocity compared to non-diabetic controls. However, diabetic animals receiving daily injections of NAALADase inhibitor (either Compound D or Compound A at a dose of 10 mg/kg) showed significantly less severe nerve conduction deficits than did

25 the diabetic controls receiving vehicle treatment. This was

WO 02/057222

PCT/US02/01205

apparent starting at 8 weeks of treatment and persisted to a similar degree through to the six month termination point of the study. Diabetic vehicles, on the other hand, showed a progressive deterioration in nerve conduction velocity from 6 to 16 weeks after start of vehicle administration which was maintained through to six months.

EXAMPLE 12

In Vivo Assay of NAALADase Inhibitors on Diabetic Neuropathy

10

in STZ Model

Motor and sensory nerve conduction velocity was also measured in STZ-diabetic animals after 4, 8 and 12 weeks of treatment (see De Koning et al., supra, for a description of the experimental method). Briefly, stimulating needle electrodes were inserted close to the sciatic and tibial nerves with recording electrodes being placed subcutaneously over the distal foot muscles, in anesthetized rats. The results are graphically presented in FIGS. 9A, 9B, 10A and 10B. Diabetic animals receiving vehicle showed a significant reduction in both motor and sensory nerve conduction compared to non-diabetic animals. Treatment with 10 mg/kg of Compound A daily for 4, 8 and 12 weeks all tended to improve (increase) both motor and sensory nerve conduction velocities, with a significant improvement being observed after 12 weeks and 8 weeks for motor and sensory nerve

WO 02/057222

PCT/US02/01205

conduction velocity, respectively (FIGS. 9A and 9B). The lower dose of Compound A tested (1 mg/kg) had similar effects. Treatment of animals with Compound D at either dose also increased both motor and sensory nerve conduction velocities above that of diabetic controls, significantly so after 12 weeks of treatment for the 10 mg/kg treatment group (FIGS. 10A and 10B) and at the earlier time periods after treatment with the 1 mg/kg dose. Thus, the results show that NAALADase inhibition alters the progression of diabetic neuropathy.

EXAMPLE 13

In Vivo Assay of NAALADase Inhibitors on Reversal of Diabetic Neuropathy in STZ Models

15 General Method for STZ Model - Delayed Dosing

Rats (200 to 225 g) were injected with STZ (70 mg/kg) into the tail vein. Diabetes (>350 mg/dl) was confirmed in all rats, 4 weeks after STZ administration. Rats were left untreated until 35 to 49 days after STZ. Compound D (1, 3, or 10 mg/kg), Compound E (10 mg/kg), or vehicle were dosed daily p.o. following confirmation of hyperalgesia and/or nerve conduction velocity deficits. In separate experiments, onset of treatment was delayed until 60 to 90 days after STZ administration. Nerve conduction velocity or withdrawal response to thermal stimulation of hind paws was

WO 02/057222

PCT/US02/01205

measured at intervals, usually bi-weekly for thermal response and monthly for nerve conduction velocity.

General Method for db/db Mice Study

Spontaneously diabetic mice (db/db mice) and non-
5 diabetic littermates were obtained from Jackson labs. Mice
were left untreated until 7 to 8 months of age (or after 4
to 5 months of chronic diabetes) and then dosed daily with
Compound F (1 mg/kg) p.o. Nerve conduction velocity was
measured prior to the onset and after eight weeks of
10 treatment.

Nerve conduction velocity measurements

Sensory and motor nerve conduction velocities were
evaluated using the method of De Koning and Gispen (*Peptides*
8: 415-422, 1987). Electrophysiological evaluation was
15 carried out within one hour of dosing. Animals were
anesthetized with isoflurane and stimulating needle
electrodes were inserted close to the sciatic nerve at the
sciatic notch and the tibial nerve near the ankle.
Recording electrodes were placed over the foot muscles.
20 Stimuli were applied and responses recorded. Motor and
sensory nerve conduction velocities were calculated by
measuring the distance between the sciatic notch and ankle
sites, and the latency between the M-wave and the H-reflex.

WO 02/057222

PCT/US02/01205

Thermal Hyperalgesia

Animals were acclimated to the apparatus for at least 5 min. An infra-red source was placed under below the plantar surface of the rat hind-paw. The intensity of the source was adjusted so that latency for normal rats was about 10 secs. Animals were tested for thermal response latency according to the method of Hargreaves et al. (Pain 77-88, 1988). Each animal was tested 8 times (4 each hind limb) and the latency of response recorded automatically to nearest 0.1 sec. An average of the last 4 measurements for each paw was calculated (8 total measurements) and noted for each rat.

FIG. 31 shows the effect of NAALADase inhibitor (Compound D and Compound E) treatment on neuropathic pain abnormalities in STZ-diabetic rats. All rats showed apparent hyperalgesia compared to non-diabetic rats prior to NAALADase inhibitor treatment (5 weeks post STZ). However, within two weeks of treatment, neuropathic hyperalgesia was reversed towards normal in both NAALADase inhibitor treated groups. This reversal persisted throughout the subsequent hypoalgesic phase usually seen in prolonged diabetic-STZ rats, with a reduced hypoalgesic phase displayed in NAALADase treated rats.

FIG. 32 shows the motor nerve conduction velocity measurements in STZ diabetic rats and non-diabetic controls

WO 02/057222

PCT/US02/01205

prior to and at time periods after NAALADase inhibitor treatment. Within 8 weeks of dosing, both NAALADase inhibitors Compound D and Compound E reversed the motor nerve conduction velocity towards normal (non-diabetic values). This effect persisted through 12 weeks of treatment.

FIG. 33 shows sensory nerve conduction velocity deficits, similarly tested. NAALADase inhibitor treatment similarly reversed sensory nerve conduction velocity deficits, significantly so after only 2 weeks of treatment.

FIG. 34 shows neuropathic pain abnormalities in another experiment where treatment with lower doses (1 and 3 mg/kg) of the NAALADase inhibitor Compound D was initiated after 7 weeks of STZ treatment. Significant reduction in pain abnormalities were again apparent with both doses of Compound D.

FIGS. 35 and 36 show sensory and motor nerve conduction velocity, respectively, in these chronically diabetic STZ rats treated with the lower doses of Compound D. Sensory nerve conduction was significantly improved towards normal within 4 weeks of treatment whereas motor nerve conduction remained unimproved by these low doses, even 8 weeks after dosing.

FIGS. 37 and 38 show sensory and motor nerve conduction velocity measurements generated from an external CRO in a

WO 02/057222

PCT/US02/01205

similar chronically diabetic STZ model, where rats were left untreated until 60 days after STZ treatment. Partial reversal of both deficits was again produced by Compound D treatment. FIG. 39 shows the same where treatment was
5 delayed yet further, until 90 days after STZ.

FIG. 40 shows nerve conduction velocity measurements from a genetic mouse model of diabetes, at 6 to 7 months of age (after about 4 months of chronic diabetes). A significant impairment in sensory NCV was apparent at this
10 time. FIG. 41 shows the nerve conduction velocity in these mice after 8 weeks of treatment with another, more potent NAALADase inhibitor administered at 1 mg/kg daily. Significant improvement in the sensory nerve conduction was apparent following drug treatment.

15

EXAMPLE 14

Effect of NAALADase Inhibitors on Onset of ALS

The effect of NAALADase inhibitors on the onset of ALS was tested using the transgenic mice model of familial
20 amyotrophic lateral sclerosis (FALS), which is detailed in Gurney, M., *Annals of Neurology* (1996) 39:147-157, and otherwise well known in the art. One month old transgenic GlH mice were treated with daily intraperitoneal injections of a vehicle (50 mM HEPES-buffered saline) or a NAALADase
25 inhibitor (50 mg/kg Compound A). Clinical symptoms of the

WO 02/057222

PCT/US02/01205

mice were monitored daily. The onset of clinical disease was scored by examining each mouse for its shaking of limbs when suspended in the air by its tail, cross spread of spinal reflexes, hindlimb paralysis, body weight and wheel running activity.

The results, set forth below in TABLE IV, show that disease onset was delayed in mice treated with a NAALADase inhibitor.

10

TABLE IV**EFFECT OF NAALADASE INHIBITOR ON ONSET OF CLINICAL DISEASE**

STUDY	DISEASE ONSET FOR COMPOUND A TREATED MICE (days)	DISEASE ONSET FOR VEHICLE TREATED MICE (days)	DIFFERENCE
Study 1	221	189	32
Study 2	166	141	25

15

EXAMPLE 15Effect of NAALADase Inhibitor on ALS Survival and Clinical Symptoms

The effect of NAALADase inhibitors on ALS survival and clinical symptoms was tested using again the transgenic mice

WO 02/057222

PCT/US02/01205

model of FALS. One month old transgenic G1H mice were treated daily with a vehicle (50 mM HEPES-buffered saline) or a NAALADase inhibitor (30 mg/kg Compound B) p.o. (by oral administration). Clinical symptoms of the mice were
5 monitored twice a week. Such symptoms included shaking of limbs, gait, dragging of hind limbs, crossing of limbs, righting reflex and mortality. Gait and crossing of limbs were graded on an arbitrary scale ranging from 0 to 3, with 0 representing most normal and 3 representing least normal,
10 e.g. severest difficulty in walking or crossing limbs. Righting reflex was measured by the time (seconds) it took the mice to right themselves when placed on their sides on a flat surface.

The results, set forth in FIGS. 24-30, show that
15 survival was prolonged and clinical symptoms were attenuated in mice treated with a NAALADase inhibitor.

EXAMPLE 16

Protective Effect of NAALADase Inhibitors in Experimental Rat

Glaucoma

EXPERIMENTAL PROTOCOL

All experiments complied with the Association for Research in Vision and Ophthalmology Statement for the Use of Animals in Ophthalmic and Vision Research. 82 male Brown
25 Norway rats (*Rattus norvegicus*), each weighing approximately

WO 02/057222

PCT/US02/01205

250 gm, were treated using procedures approved by the Animal Care Committee of the Johns Hopkins University School of Medicine. The rats were housed with a 12 hour light/12 hour dark cycle and fed *ad libitum*.

5 EXPERIMENTAL GLAUCOMA: Unilateral elevation of intraocular pressure ("IOP") was produced in 56 rats by microinjection of hypertonic saline into episcleral veins, following procedures described in Morrison, J. et al., *IOVS* (March 1998) 39:526-531. Beginning on the day of IOP elevation,
10 the rats were treated daily with intraperitoneal injections of either a vehicle (23 rats with 50 mM HEPES-buffered saline) or a NAALADase inhibitor (11 rats with 10 mg/kg of Compound A and 22 rats with 10 mg/kg of Compound B). 11 saline treated rats, 11 Compound A treated rats and 11
15 Compound B treated rats were sacrificed at 8 weeks, and the remaining rats at 12 weeks, after initial IOP elevation.

OPTIC NERVE TRANSECTION: The optic nerve was transected unilaterally in 26 rats under intraperitoneal pentobarbital anesthesia. The conjunctiva was opened with scissors and
20 the optic nerve exposed by traction on extraocular muscles. The transection was performed with microscissors 5 mm posterior to the globe, with specific attention to avoidance of injury to major ocular blood vessels. Immediately after transection, the retina was examined ophthalmoscopically to
25 assure that the retinal arterial blood supply was not

WO 02/057222

PCT/US02/01205

disrupted. The conjunctiva was closed with absorbable suture and the eye dressed with antibiotic ointment. Beginning on the day of transection, the rats were treated daily with intraperitoneal injections of either a vehicle (9 rats with 50 mM HEPES-buffered saline) or a NAALADase inhibitor (8 rats with 10 mg/kg of Compound A and 9 rats with 10 mg/kg of Compound B). 5 saline treated rats, 3 Compound A treated rats and 4 Compound B treated rats were sacrificed at 2 weeks, and the remaining rats at 4 weeks, after transection.

OPTIC NERVE COUNTING: The rats were sacrificed by exsanguination under deep pentobarbital anesthesia. They were perfused through the heart with 2% paraformaldehyde/2% glutaraldehyde in 0.1 M phosphate buffer, pH 7.2, and the eyes with attached optic nerves were removed. A cross-section of the optic nerve from both experimental (glaucoma or transection) and control eyes was removed 1.5 mm posterior to the globe, 1 mm in thickness, and post-fixed in 2% osmium tetroxide in buffer. These were processed into epoxy resin, sectioned at 1 micron and stained with toluidine blue.

The area of the optic nerve cross-section was measured by outlining its outer border at 10x magnification on an image analysis system (Universal Imaging Corp., Westchester, PA) with Synsys digital camera and Metamorph software.

WO 02/057222

PCT/US02/01205

Three area measurements were taken and the mean value was determined. To measure the density and fiber diameter distributions, images were captured with a 100x phase contrast objective from 10 different areas of each nerve.

5 These were edited to eliminate non-neural objects and the size of each axon internal to the myelin sheath (its minimum diameter) and the density of axons/square mm were calculated for each image and nerve. The mean density was multiplied by total nerve area to yield fiber number for each nerve.

10 The total fiber number in glaucoma or transection nerves was compared to the normal, fellow eye of each rat to yield a percent loss value. The number of axons counted among the 10 images was an approximately 20% sample of the 80-90,000 axons in normal rat nerves. The person measuring axon

15 number was masked to the protocol conducted on the nerves.

RESULTS

EXPERIMENTAL GLAUCOMA: The mean fiber percent difference in the saline-treated, control rats was significantly lower in their glaucoma eyes compared to their normal eyes, with a

20 mean fiber loss of $14.44 \pm 5.75 \%$ ($n = 11$ rats; TABLE V) in the 8 week follow-up group, and $8.15 \pm 7.84 \%$ in the 12 week follow-up group ($n = 12$ rats; TABLE VI).

By contrast, there was no significant loss of fibers in either the 8 week or 12 week NAALADase inhibitor-treated

25 rats. The mean percent fiber loss in each NAALADase

WO 02/057222

PCT/US02/01205

inhibitor-treated group was statistically less than the loss in the saline-treated, control groups (at 8 weeks, $p = 0.05$ for Compound A and $p = 0.02$ for Compound B).

5

TABLE V

EXPERIMENTAL GLAUCOMA RESULTS

8 WEEK GROUP	N	IOP INTEGRAL DIFFERENCE	FIBER NUMBER	PERCENT DIFFERENCE
Compound A	11	85 ± 37.5	79156 ± 2436 *	-1.82 ± 2.92
Compound B	11	116 ± 33.2	80785 ± 2121 **	-0.82 ± 2.97
Control	11	104 ± 26.4	68295 ± 4617	14.44 ± 5.75

10

TABLE VI

EXPERIMENTAL GLAUCOMA RESULTS

12 WEEK GROUP	N	IOP INTEGRAL DIFFERENCE	FIBER NUMBER	PERCENT DIFFERENCE
Compound B	11	109 ± 45.2	90504 ± 1718	-3.21 ± 2.86
Control	12	158 ± 66.5	79827 ± 6783	8.15 ± 7.84

15

IOP Integral Difference = difference in IOP exposure between

WO 02/057222

PCT/US02/01205

glaucoma eye and normal eye in each rat (mm Hg -- days).

Percent Difference = mean percent difference in fiber number
between glaucoma and normal eye in each rat (positive value
5 indicates fewer fibers in the glaucoma eye).

Differences in IOP Integral Difference are not significant
($p > 0.05$).

10 Differences in Percent Difference between drug-treated and
saline-treated, control rats at 8 weeks post insult are
significant ($p = 0.05^*$ and $p = 0.02^{**}$).

OPTIC NERVE TRANSECTION: The experimental transection data
15 suggest a slowing or rescue of ultimate RGC death in rats
treated with NAALADase inhibitors at 2 weeks after
transection. At 2 weeks after transection, both drug-
treated groups had more remaining RGC axons than did the
saline-treated, control group, judged either by absolute
20 number of fibers or percent difference between transected
eye and normal eye in each rat (TABLE VII). Rats treated
with Compound A and Compound B had, respectively, 3 times
and twice as many remaining axons as the saline-treated
rats. All or nearly all RGC die within the first 2 months
25 after transection, regardless of any pharmacological

WO 02/057222

PCT/US02/01205

treatment. Thus, by 4 weeks after transection, more than 80% of RGC axons were gone in all groups (TABLE VIII). At 4 weeks after transection, there were no significant differences between the drug-treated rats and the saline-
5 treated rats.

TABLE VII

OPTIC NERVE TRANSECTION

2 WEEKS SURVIVAL	N	FIBER NUMBER	PERCENT DIFFERENCE
Compound A	3	26,426 \pm 23,025	65.3 \pm 30.9
Compound B	4	19,550 \pm 11,383	75.3 \pm 14.8
Control	5	8,220 \pm 9,337	90.2 \pm 10.7

10

TABLE VIII

OPTIC NERVE TRANSECTION

4 WEEKS SURVIVAL	N	FIBER NUMBER	PERCENT DIFFERENCE
Compound A	5	13,599 \pm 7,868	82.4 \pm 8.9
Compound B	5	5,162 \pm 5,017	93.4 \pm 6.2
Control	4	10,449 \pm 8,157	86.9 \pm 10.6

15

WO 02/057222

PCT/US02/01205

Percent Difference = mean percent difference in fiber number between glaucoma and normal eye in each rat (positive value indicates fewer fibers in the glaucoma eye).

- 5 Differences in Percent Difference between drug-treated and saline-treated, control rats are not statistically significant ($p = 0.05$).

EXAMPLE 17

10 Neuroprotective Effect of NAALADase Inhibitors in
Transgenic Mouse Model of Huntington's Disease

Behavioral testing (rotarod)

Transgenic HD mice of the N171-82Q strain and non-transgenic littermates were treated with NAALADase inhibitor
15 Compound B (30 mg/kg) or a vehicle from 10 weeks of age. The mice were placed on a rotating rod ("rotarod"). The length of time at which the mouse fell off the rotarod was recorded as a measure of motor coordination. FIG. 42 shows that transgenic HD mice treated with Compound B stayed
20 longer on the rotarod than similar transgenic HD mice treated with a vehicle. The treatment with Compound B had no effect on the rotarod performance of normal non-HD mice.

The total distance traveled by the mice was also recorded as a measure of overall locomotion. FIG. 43 shows
25 that while the vehicle treated HD mice demonstrated the

WO 02/057222

PCT/US02/01205

lowest mean locomotor score, the treatment with NAALADase inhibitor had no apparent effect on overall locomotion.

Survival

The effects of Compound B and vehicle on the survival of transgenic HD mice (N171-82Q) were evaluated. Thirteen mice (six male and seven female) were assigned to the Compound B treatment group, and fourteen mice (six male and eight female) were assigned to the vehicle treatment group. Treatment was continued until all the mice died.

FIG. 44 shows the survival distributions over time by treatment group. The median survival time is 184 days for the Compound B treatment group, and 158.5 days for the vehicle treatment group. Although the Compound B treatment group had a longer median survival time than the vehicle treatment group, the difference is not statistically significant (p-value = 0.07).

FIGS. 45 and 46 show the survival distributions over time by treatment group and sex. When analyzing the results specific to sex, female mice treated with Compound B had significantly prolonged survival time (p-value = 0.03) compared to their vehicle treated counterparts. Within the vehicle treatment group, the

WO 02/057222

PCT/US02/01205

males have better survival times than the females although this trend was not observed in the Compound B treatment group. The data suggest that sex may influence survival distributions over time.

5

EXAMPLE 18

A patient is suffering from any disease, disorder or condition where NAALADase levels are altered, including any of the diseases, disorders or conditions described above.

10 The patient may then be administered an effective amount of a compound of the invention. It is expected that after such treatment, the patient would not suffer any significant injury due to, would be protected from further injury due to, or would recover from the disease, disorder or condition.

15 All publications, patents and patent applications identified above are herein incorporated by reference, as though set forth herein in full.

The invention being thus described, it will be apparent to those skilled in the art that the same may be varied in

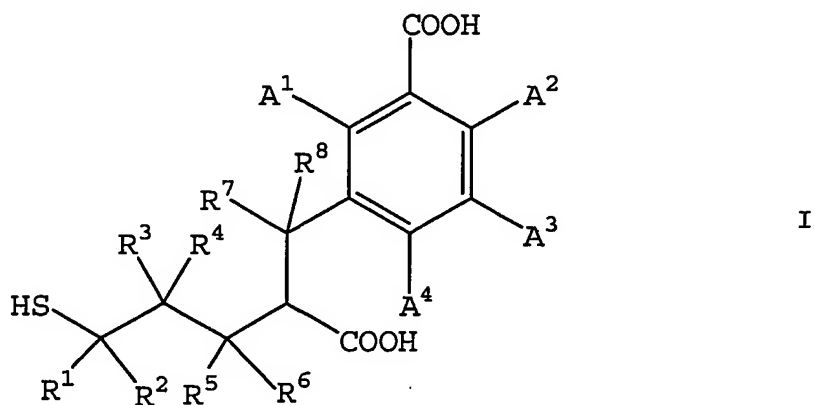
20 many ways without departing from the spirit and scope of the invention. Such variations are included within the scope of the following claims.

WO 02/057222

PCT/US02/01205

WE CLAIM:

1. A compound of formula I



- 5 or a pharmaceutically acceptable equivalent of said compound, wherein:

R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 and R^8 are independently hydrogen or C_1 - C_3 alkyl;

A^1 , A^2 , A^3 and A^4 are independently hydrogen, C_1 - C_6 alkyl,
 10 C_1 - C_6 alkoxy, halo, nitro, phenyl, phenoxy, benzyl, benzyloxy
 or -COOH, or any adjacent two of A^2 , A^3 and A^4 form with the
 benzene ring a fused 5- or 6-membered carbocyclic or
 heterocyclic aromatic ring, said heterocyclic aromatic ring
 containing 1 or 2 oxygen, nitrogen and/or sulfur
 15 heteroatom(s).

2. The compound of claim 1, wherein:

WO 02/057222

PCT/US02/01205

R¹, R², R³, R⁴, R⁵, R⁶, R⁷ and R⁸ are independently hydrogen or methyl; and

A¹, A², A³ and A⁴ are independently hydrogen, C₁-C₄ alkyl, C₁-C₂ alkoxy, halo, nitro, phenyl, phenoxy, benzyloxy, nitro or
5 -COOH.

3. The compound of claim 1, wherein any adjacent two of A², A³ and A⁴ form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said
10 heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s).

4. The compound of claim 1, wherein said compound is selected from the group consisting of:

15 3-carboxy- α -(3-mercaptopropyl)-benzenepropanoic acid;

5-(2-carboxy-5-mercaptopentyl)-1,3-benzenedicarboxylic acid;

5-carboxy-2-chloro- α -(3-mercaptopropyl)-
20 benzenepropanoic acid;

3-carboxy-4-fluoro- α -(3-mercaptopropyl)-benzenepropanoic acid;

3-carboxy-2-chloro- α -(3-mercaptopropyl)-benzenepropanoic acid;

WO 02/057222

PCT/US02/01205

- 3-carboxy-4-chloro-alpha-(3-mercaptopropyl)-
benzenepropanoic acid;
- 5-carboxy-2-fluoro-alpha-(3-mercaptopropyl)-
benzenepropanoic acid;
- 5 5-carboxy-alpha-(3-mercaptopropyl)-2-methoxy-
benzenepropanoic acid;
- 3-bromo-5-carboxy-alpha-(3-mercaptopropyl)-
benzenepropanoic acid;
- 3-carboxy-alpha-(3-mercaptopropyl)-5-nitro-
10 benzenepropanoic acid;
- 3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-
mercaptopropyl)-benzenepropanoic acid;
- 5-carboxy-alpha-(3-mercaptopropyl)-2-nitro-
benzenepropanoic acid;
- 15 2-bromo-5-carboxy-alpha-(3-mercaptopropyl)-
benzenepropanoic acid;
- (+)-3-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic
acid;
- (-)-3-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic
20 acid;
- 5-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-3-
carboxylic acid;
- 2-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-4-
carboxylic acid;

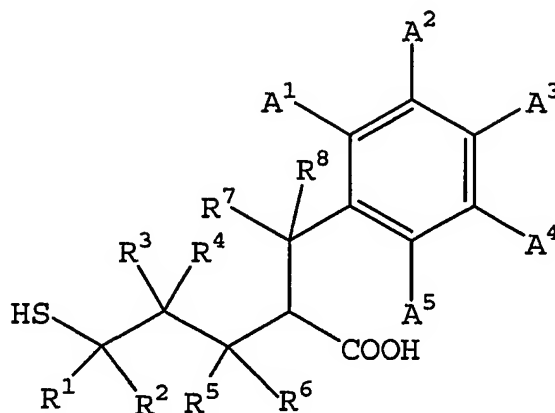
WO 02/057222

PCT/US02/01205

- 6-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-2-carboxylic acid;
- 4-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-2-carboxylic acid;
- 5 3-carboxy-alpha-(3-mercaptopropyl)-5-methoxy-benzenepropanoic acid;
- 3-carboxy-alpha-(3-mercaptobutyl)-benzenepropanoic acid;
- 3-carboxy-alpha-(3-mercaptopropyl)-5-(phenylmethoxy)-
- 10 benzenepropanoic acid;
- 3-carboxy-alpha-(3-mercaptopropyl)-5-phenoxy-benzenepropanoic acid;
- 3-carboxy-5-(1,1-dimethylethyl)-alpha-(3-mercaptobutyl)-benzenepropanoic acid; and
- 15 pharmaceutically acceptable equivalents.
5. The compound of claim 1, wherein said compound is an enantiomer or an enantiomer-enriched mixture.
- 20 6. A compound of formula II

WO 02/057222

PCT/US02/01205



II

or a pharmaceutically acceptable equivalent of said compound, wherein:

R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 and R^8 are independently,
5 hydrogen or C_1 - C_3 alkyl; and

A^1 , A^2 , A^3 , A^4 and A^5 are independently hydrogen, C_1 - C_6 alkyl, C_1 - C_6 alkoxy, C_1 - C_3 perhaloalkyl, phenyl, phenoxy, benzyl, benzyloxy, hydroxy, halo, cyano, nitro, $-SO_2R^9$, $-(C=O)NR^9R^{10}$, $-(C=O)NR^9(CH_2)_nCOOH$, $-NR^9(C=O)R^{10}$, $-(CH_2)_nCOOH$ or -
10 $COOH$, or any adjacent two of A^1 , A^2 , A^3 , A^4 and A^5 form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s);

15 R^9 and R^{10} are independently hydrogen, C_1 - C_6 alkyl, phenyl or benzyl; and

n is 1-3;

WO 02/057222

PCT/US02/01205

provided that if A¹, A³ and A⁵ are independently hydrogen, C₁-C₆ alkyl, C₁-C₆ alkoxy, halo, nitro, phenyl, phenoxy, benzyl, benzyloxy or -COOH, then neither A² nor A⁴ are -COOH; and provided that if any adjacent two of A³, A⁴ and A⁵ form with the benzene ring a fused 5- or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s), then A² is not -COOH.

10 7. The compound of claim 6, wherein:

R¹, R², R³, R⁴, R⁵, R⁶, R⁷ and R⁸ are each hydrogen;

A¹, A², A³, A⁴ and A⁵ are independently hydrogen, C₁-C₄ alkyl, C₁-C₂ alkoxy, C₁-C₂ perhaloalkyl, phenyl, phenoxy, hydroxy, halo, cyano, nitro, -SO₂R⁹, - (C=O)NR⁹R¹⁰,
15 - (C=O)NR⁹(CH₂)COOH, -NR⁹(C=O)R¹⁰ or - (CH₂)COOH; and

R⁹ and R¹⁰ are independently hydrogen, methyl or benzyl.

8. The compound of claim 6, wherein any adjacent two of A¹, A², A³, A⁴ and A⁵ form with the benzene ring a fused 5-
20 or 6-membered carbocyclic or heterocyclic aromatic ring, said heterocyclic aromatic ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s).

9. The compound of claim 6, wherein said compound is
25 selected from the group consisting of:

WO 02/057222

PCT/US02/01205

- alpha- (3-mercaptopropyl) -3- (trifluoromethyl) -
benzenepropanoic acid;
- alpha- (3-mercaptopropyl) -benzenepropanoic acid;
- 4-hydroxy-alpha- (3-mercaptopropyl) -benzenepropanoic
5 acid;
- 2,3,4,5,6-pentafluoro-alpha- (3-mercaptopropyl) -
benzenepropanoic acid;
- 4-carboxy-alpha- (3-mercaptopropyl) -benzenepropanoic
acid;
- 10 alpha- (3-mercaptopropyl) -4- (methylsulfonyl) -
benzenepropanoic acid;
- 2-cyano-alpha- (3-mercaptopropyl) -benzenepropanoic acid;
- 2- (aminocarbonyl) -alpha- (3-mercaptopropyl) -
benzenepropanoic acid;
- 15 alpha- (3-mercaptopropyl) -2,5-dimethoxy-benzenepropanoic
acid;
- alpha- (3-mercaptopropyl) -3-phenoxy-benzenepropanoic
acid;
- alpha- (3-mercaptopropyl) -4-phenyl-benzenepropanoic
20 acid;
- 4- (acetylamino) -alpha- (3-mercaptopropyl) -
benzenepropanoic acid;
- 4- (carboxymethyl) -alpha- (3-mercaptopropyl) -
benzenepropanoic acid;

WO 02/057222

PCT/US02/01205

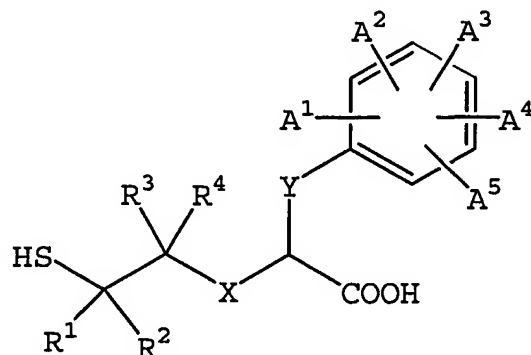
- 4-carboxy-alpha (3-mercaptopropyl) -1-naphthalenepropanoic acid;
- 2-carboxy-alpha-(3-mercaptopropyl)-benzenepropanoic acid;
- 5 4-carboxy-2,3,5,6-tetrafluoro-alpha-(3-mercaptopropyl)-benzenepropanoic acid;
- alpha-(3-mercaptopropyl)-2-naphthalenepropanoic acid;
- 2-chloro-alpha-(3-mercaptopropyl)-benzenepropanoic acid;
- 10 alpha-(3-mercaptopropyl)-3-[[(phenylmethyl) amino]-carbonyl]benzenepropanoic acid;
- 3-[[(carboxymethyl) amino] carbonyl]-alpha-(3-mercaptopropyl)-benzenepropanoic acid;
- 3-bromo-4-carboxy-alpha-(3-mercaptopropyl)-
- 15 benzenepropanoic acid;
- alpha-(3-mercaptopropyl)-3-phenyl-benzenepropanoic acid;
- 3-(1,1-dimethylethyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid; and
- 20 pharmaceutically acceptable equivalents.

10. The compound of claim 6, wherein said compound is an enantiomer or an enantiomer-enriched mixture.

25 11. A compound of formula III

WO 02/057222

PCT/US02/01205



III

or a pharmaceutically acceptable equivalent of said compound, wherein:

X and Y are independently $-CR^5R^6-$, $-O-$, $-S-$ or $-NR-$,
 5 provided that at least one of X and Y is/are $-CR^5R^6-$;

A^1 , A^2 , A^3 , A^4 and A^5 are independently hydrogen, C_1-C_9 alkyl, C_2-C_9 alkenyl, C_2-C_9 alkynyl, aryl, heteroaryl, carbocycle, heterocycle, C_1-C_9 alkoxy, C_2-C_9 alkenyloxy, phenoxy, benzyloxy, hydroxy, halo, nitro, cyano, isocyano, -
 10 $COOR^7$, $-COR^7$, $-NR^7R^8$, $-SR^7$, $-SOR^7$, $-SO_2R^7$, $-SO_2(OR^7)$, $-(C=O)NR^7R^8$, $-(C=O)NR^7(CH_2)_nCOOH$, $-NR^7(C=O)R^8$ or $-(CH_2)_nCOOH$, or any adjacent two of A^1 , A^2 , A^3 , A^4 and A^5 form with the benzene ring a fused ring that is saturated or unsaturated, aromatic or non-aromatic, and carbocyclic or heterocyclic, said heterocyclic
 15 ring containing 1 or 2 oxygen, nitrogen and/or sulfur heteroatom(s);

n is 1-3;

WO 02/057222

PCT/US02/01205

R, R¹, R², R³, R⁴, R⁵, R⁶, R⁷ and R⁸ are independently hydrogen, C₁-C₉ alkyl, C₂-C₉ alkenyl, C₂-C₉ alkynyl, aryl, heteroaryl, carbocycle or heterocycle; and

said alkyl, alkenyl, alkynyl, aryl, heteroaryl, carbocycle, heterocycle, alkoxy, alkenyloxy, phenoxy, benzyloxy, and fused ring are independently unsubstituted or substituted with one or more substituent(s);

provided that if A¹, A² and A³ are each hydrogen, and A⁴ and A⁵ are each -COOH, then A⁴ is ortho to A⁵; and provided that if Y is -CR⁵R⁶-, then at least one of A¹, A², A³, A⁴ and A⁵ is/are independently phenoxy, benzyloxy, aryl, heteroaryl, carbocycle or heterocycle that is substituted with one or more substituent(s).

12. The compound of claim 11, wherein:

Y is -O-, -S- or -NR-;

A¹, A², A³, A⁴ and A⁵ are independently hydrogen, C₁-C₄ alkyl, C₁-C₂ alkoxy, hydroxy, halo, -COOH, -COR⁷, -NR⁷(C=O)R⁸ or -(CH₂)COOH; and

R⁷ and R⁸ are independently hydrogen or methyl.

13. The compound of claim 11, wherein:

Y is -CR⁵R⁶-;

A¹, A², A³ and A⁴ are each hydrogen; and

WO 02/057222

PCT/US02/01205

A⁵ is phenoxy, benzyloxy, aryl, heteroaryl, carbocycle or heterocycle, wherein said phenoxy and benzyloxy are substituted with -COOH, and said aryl, heteroaryl, carbocycle and heterocycle are substituted with one or more
5 substituent(s) selected from the group consisting of cyano and -COOH.

14. The compound of claim 11, wherein said compound is selected from the group consisting of:

- 10 4-(2-cyanophenyl)-alpha-(3-mercaptopropyl)-benzenepropanoic acid;
- 3-(1-carboxy-4-mercaptobutoxy)-benzoic acid;
- 5-mercapto-2-phenoxy-pentanoic acid;
- 2-(3,5-dimethoxyphenoxy)-5-mercapto-pentanoic acid;
- 15 2-(3-hydroxyphenoxy)-5-mercapto-pentanoic acid;
- 3-(1-carboxy-4-mercaptobutoxy)-benzeneacetic acid;
- 4-(1-carboxy-4-mercaptobutoxy)-benzeneacetic acid;
- 2-(3-acetylphenoxy)-5-mercapto-pentanoic acid;
- 2-[3-(acetylamino)phenoxy]-5-mercapto-pentanoic acid;
- 20 2-(4-acetylphenoxy)-5-mercaptopentanoic acid;
- 3-(1-carboxy-4-mercaptobutoxy)-4-methoxy-benzoic acid;
- 2-(1-carboxy-4-mercaptobutoxy)-benzoic acid;
- 4-(1-carboxy-4-mercaptobutoxy)-benzoic acid;
- 3-(1-carboxy-4-mercaptobutoxy)-4-chloro-benzoic acid;
- 25 3-(1-carboxy-4-mercaptobutoxy)-4-fluoro-benzoic acid;

WO 02/057222

PCT/US02/01205

- 5-mercapto-2-(phenylthio)-pentanoic acid;
3-[1-carboxy-4-mercaptobutyl)thio]-benzoic acid;
3'-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-3-
carboxylic acid;
5 3'-(2-carboxy-5-mercaptopentyl)-[1,1'-biphenyl]-2-
carboxylic acid;
3-(2-carboxyphenoxy)-alpha-(3-mercaptopropyl)-
benzenepropanoic acid;
4-(2-carboxyphenoxy)-alpha-(3-mercaptopropyl)-
10 benzenepropanoic acid;
4'-(2-carboxy-5-mercaptopropyl)-[1,1'-biphenyl]-2-
carboxylic acid;
3-(1-carboxy-4-mercaptobutoxy)-5-(1,1-dimethylethyl)-
benzoic acid;
15 3-[(1-carboxy-4-mercaptobutyl)thio]-5-(1,1-
dimethylethyl)-benzoic acid;
3-[(1-carboxy-4-mercaptobutyl)amino]-5-(1,1-
dimethylethyl)-benzoic acid; and
pharmaceutically acceptable equivalents.
- 20
15. The compound of claim 11, wherein said compound is
an enantiomer or an enantiomer-enriched mixture.

16. A method for inhibiting NAALADase enzyme activity,
25 treating a glutamate abnormality, effecting a neuronal

WO 02/057222

PCT/US02/01205

activity, treating a prostate disease, treating cancer, inhibiting angiogenesis or effecting a TGF- β activity, comprising administering to a mammal in need of such inhibition, treatment or effect, an effective amount of a
5 compound of claim 1.

17. The method of claim 16, wherein said method is for treating a glutamate abnormality selected from the group consisting of a compulsive disorder, stroke,
10 demyelinating disease, schizophrenia, Parkinson's disease, amyotrophic lateral sclerosis, anxiety, anxiety disorder, memory impairment and glaucoma.

18. The method of claim 17, wherein the glutamate
15 abnormality is a compulsive disorder that is alcohol, nicotine or cocaine dependence.

19. The method of claim 16, wherein said method is for effecting a neuronal activity selected from the group
20 consisting of stimulation of damaged neurons, promotion of neuronal regeneration, prevention of neurodegeneration and treatment of a neurological disorder.

20. The method of claim 19, wherein the neuronal

WO 02/057222

PCT/US02/01205

activity is treatment of a neurological disorder and said neurological disorder is pain, diabetic neuropathy, peripheral neuropathy caused by physical injury or disease state, traumatic brain injury, physical damage to
5 spinal cord, stroke associated with brain damage, a demyelinating disease or a neurological disorder relating to neurodegeneration.

21. The method of claim 20, wherein said pain is
10 diabetic neuropathic pain.

22. The method of claim 21, wherein said compound is administered in combination with an effective amount of morphine.

15

23. The method of claim 20, wherein the neurological disorder relating to neurodegeneration is Parkinson's disease.

20 24. The method of claim 20, wherein the neurological disorder relating to neurodegeneration is amyotrophic lateral sclerosis.

WO 02/057222

PCT/US02/01205

25. The method of claim 16, wherein said method is for treating a prostate disease that is prostate cancer.

26. The method of claim 16, wherein said method is for
5 treating cancer.

27. The method of claim 26, wherein said cancer is of the brain, kidney or testis.

10 28. The method of claim 16, wherein said method is for inhibiting angiogenesis.

29. The method of claim 16, wherein said method is for effecting a TGF- β activity.

15

30. The method of claim 29, wherein said effecting a TGF- β activity is increasing, reducing or regulating TGF- β levels, or treating a TGF- β abnormality.

20 31. The method of claim 30, wherein said effecting a TGF- β activity is treating a TGF- β abnormality, and said TGF- β abnormality is neurodegenerative disorder, extra-cellular matrix formation disorder, cell-growth related disease, infectious disease, immune related disease,

WO 02/057222

PCT/US02/01205

epithelial tissue scarring, collagen vascular disease, fibroproliferative disorder, connective tissue disorder, inflammation, inflammatory disease, respiratory distress syndrome, infertility or diabetes.

5

32. A method for inhibiting NAALADase enzyme activity, treating a glutamate abnormality, effecting a neuronal activity, treating a prostate disease, treating cancer, inhibiting angiogenesis or effecting a TGF- β activity, .
10 comprising administering to a mammal in need of such inhibition, treatment or effect, an effective amount of a compound of claim 6.

33. A method for inhibiting NAALADase enzyme activity, .
15 treating a glutamate abnormality, effecting a neuronal activity, treating a prostate disease, treating cancer, inhibiting angiogenesis or effecting a TGF- β activity, comprising administering to a mammal in need of such inhibition, treatment or effect, an effective amount of a
20 compound of claim 11.

34. A method for detecting a disease, disorder or .
condition where NAALADase levels are altered, comprising:

WO 02/057222

PCT/US02/01205

(i) contacting a sample of bodily tissue or fluid with an effective amount of a compound of claim 1, wherein said compound binds to any NAALADase in said sample; and

(ii) measuring the amount of any NAALADase bound to
5 said sample, wherein the amount of NAALADase is diagnostic for said disease, disorder or condition.

35. A method for detecting a disease, disorder or condition where NAALADase levels are altered, comprising:

10 (i) contacting a sample of bodily tissue or fluid with an effective amount of a compound of claim 6, wherein said compound binds to any NAALADase in said sample; and

(ii) measuring the amount of any NAALADase bound to said sample, wherein the amount of NAALADase is diagnostic
15 for said disease, disorder or condition.

36. A method for detecting a disease, disorder or condition where NAALADase levels are altered, comprising:

(i) contacting a sample of bodily tissue or fluid with
20 an effective amount of a compound of claim 11, wherein said compound binds to any NAALADase in said sample; and

(ii) measuring the amount of any NAALADase bound to said sample, wherein the amount of NAALADase is diagnostic for said disease, disorder or condition.

25

WO 02/057222

PCT/US02/01205

37. A method for detecting a disease, disorder or condition where NAALADase levels are altered in a mammal, comprising:

- (i) labeling a compound of claim 1 with an effective
5 amount of an imaging reagent;
- (ii) administering to said mammal an effective amount of the labeled compound;
- (iii) allowing said labeled compound to localize and bind to NAALADase present in said mammal; and
- 10 (iv) measuring the amount of NAALADase bound to said labeled compound, wherein the amount of NAALADase is diagnostic for said disease, disorder or condition.

38. A method for detecting a disease, disorder or
15 condition where NAALADase levels are altered in a mammal, comprising:

- (i) labeling a compound of claim 6 with an effective amount of an imaging reagent;
- (ii) administering to said mammal an effective amount
20 of the labeled compound;
- (iii) allowing said labeled compound to localize and bind to NAALADase present in said mammal; and
- (iv) measuring the amount of NAALADase bound to said labeled compound, wherein the amount of NAALADase is
25 diagnostic for said disease, disorder or condition.

WO 02/057222

PCT/US02/01205

39. A method for detecting a disease, disorder or condition where NAALADase levels are altered in a mammal, comprising:

(i) labeling a compound of claim 11 with an effective
5 amount of an imaging reagent;

(ii) administering to said mammal an effective amount of the labeled compound;

(iii) allowing said labeled compound to localize and bind to NAALADase present in said mammal; and

10 (iv) measuring the amount of NAALADase bound to said labeled compound, wherein the amount of NAALADase is diagnostic for said disease, disorder or condition.

40. A diagnostic kit for detecting a disease, disorder
15 or condition where NAALADase levels are altered, comprising a compound of claim 1 labeled with a marker.

41. A diagnostic kit for detecting a disease, disorder or condition where NAALADase levels are altered, comprising
20 a compound of claim 6 labeled with a marker.

42. A diagnostic kit for detecting a disease, disorder or condition where NAALADase levels are altered, comprising a compound of claim 11 labeled with a marker.

25

WO 02/057222

PCT/US02/01205

43. A pharmaceutical composition comprising:

- (i) an effective amount of a compound of claim 1; and
- (ii) a pharmaceutically acceptable carrier.

5

44. A pharmaceutical composition comprising:

- (i) an effective amount of a compound of claim 6; and
- (ii) a pharmaceutically acceptable carrier.

45. A pharmaceutical composition comprising:

10

- (i) an effective amount of a compound of claim 11; and
- (ii) a pharmaceutically acceptable carrier.

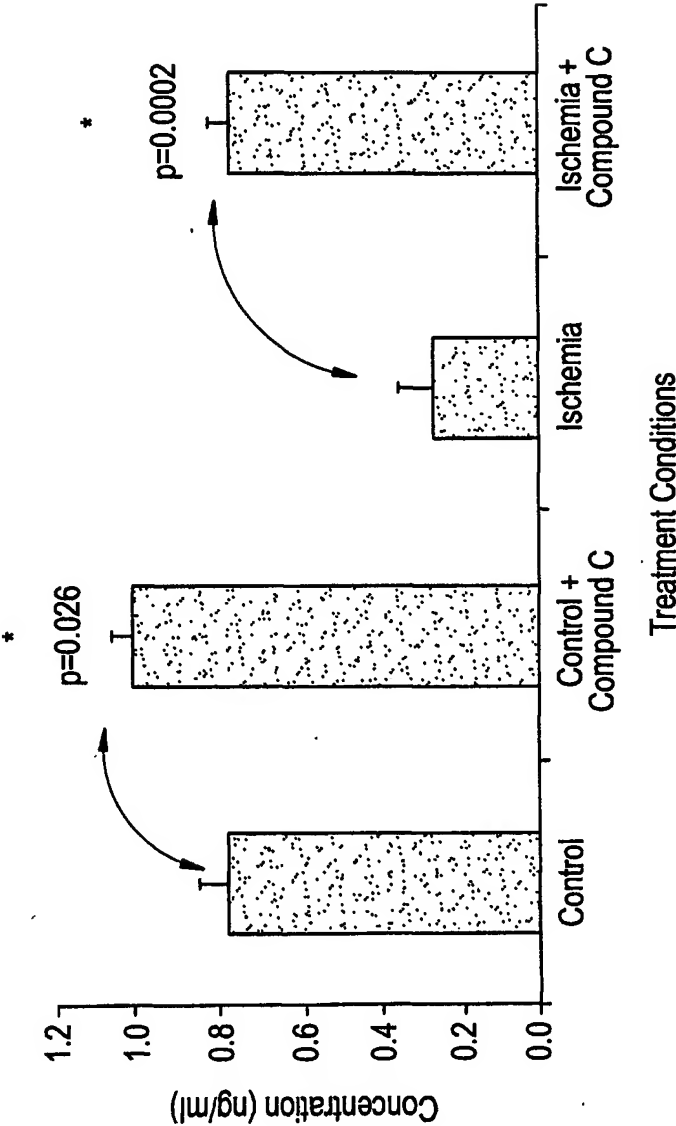
WO 02/057222

PCT/US02/01205

1/45

FIG. 1

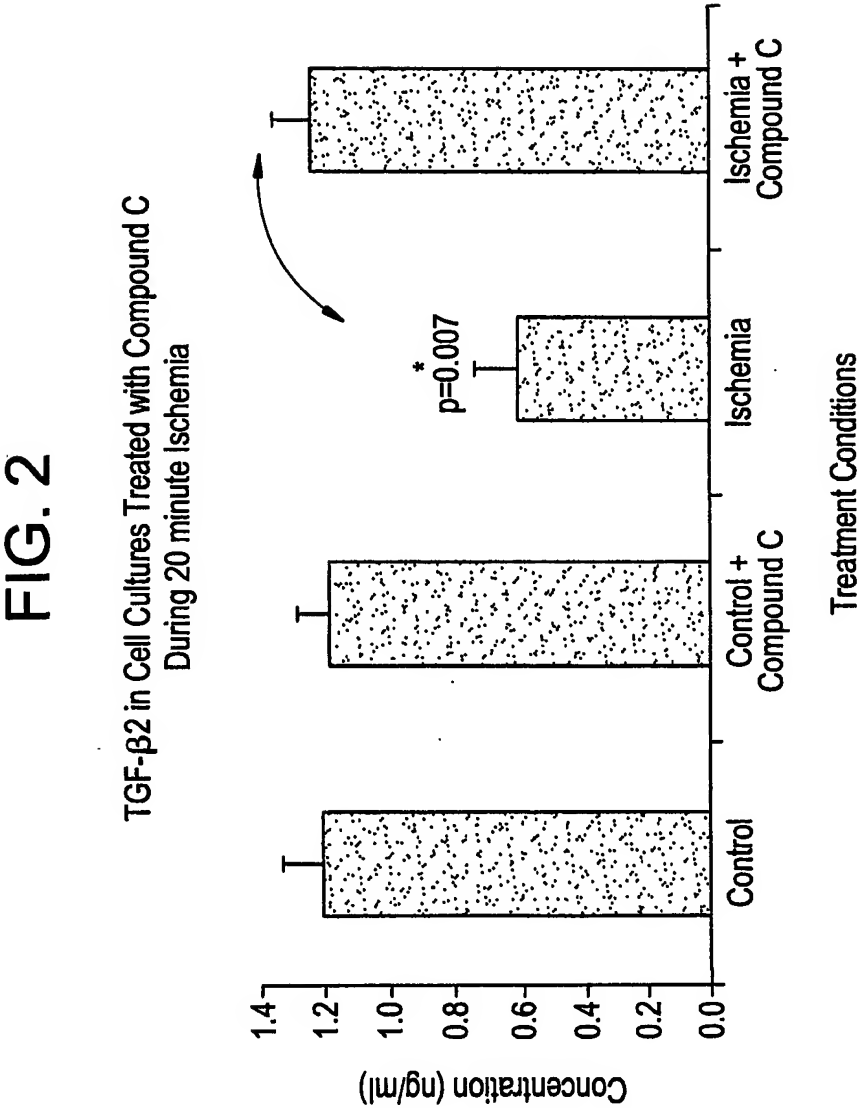
TGF-β1 in Cell Cultures Treated with Compound C
During 20 minute Ischemia



WO 02/057222

PCT/US02/01205

2/45



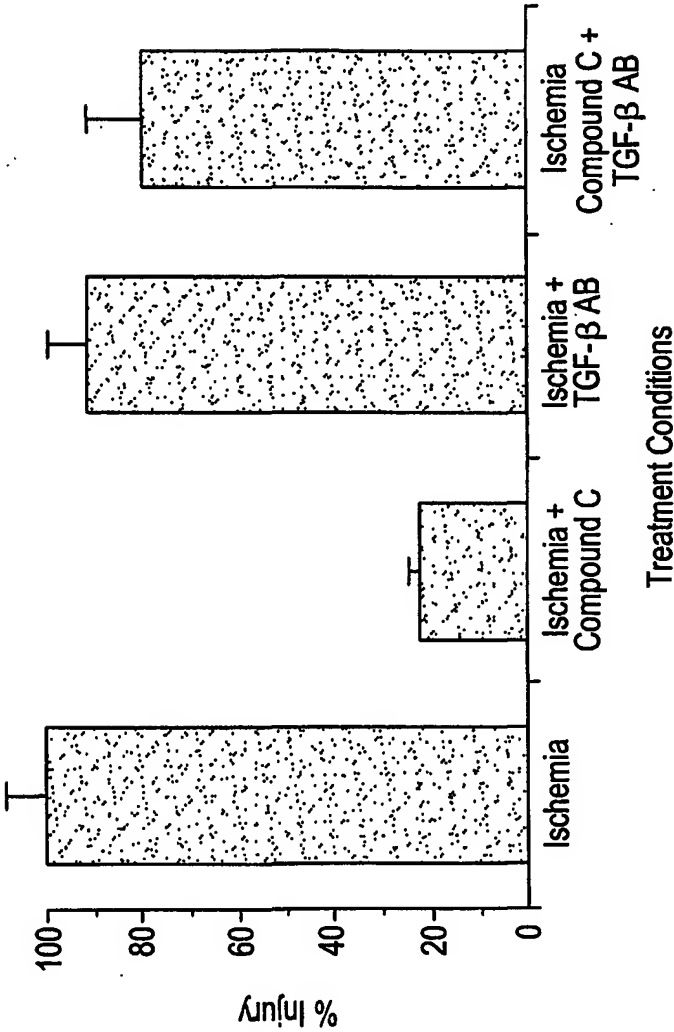
WO 02/057222

PCT/US02/01205

3/45

FIG. 3

TGF- β Neutralizing Antibody Blocks the
Neuroprotective Effect of Compound C

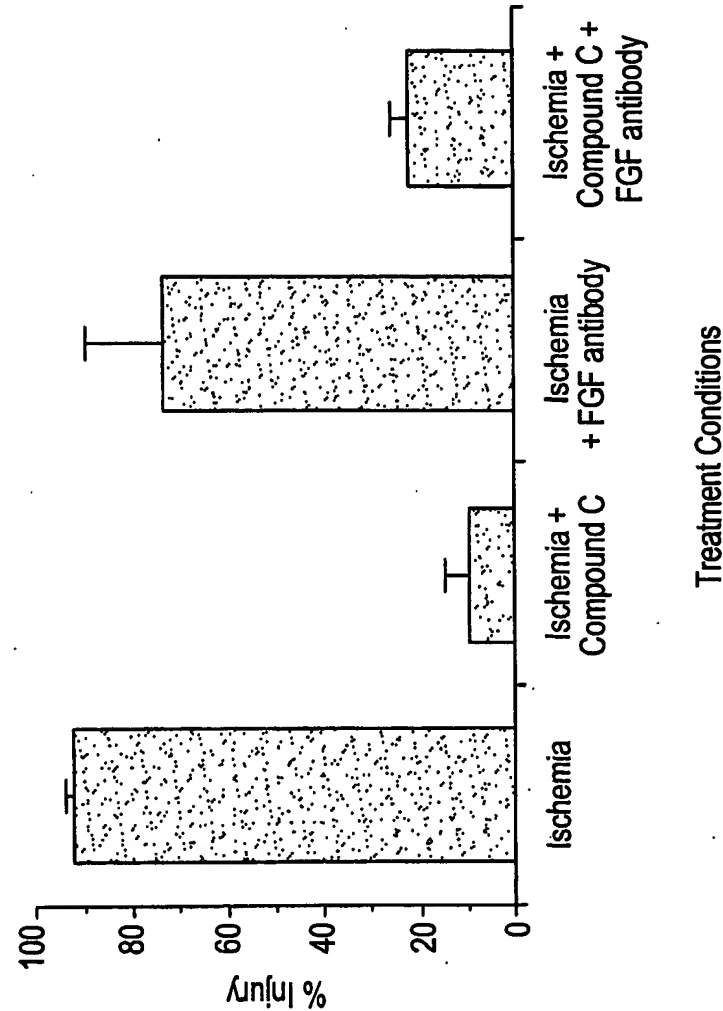


WO 02/057222

PCT/US02/01205

4/45

FIG. 4
FGF Neutralizing Antibody Does Not Block
Neuroprotective Effects of Compound C in vitro



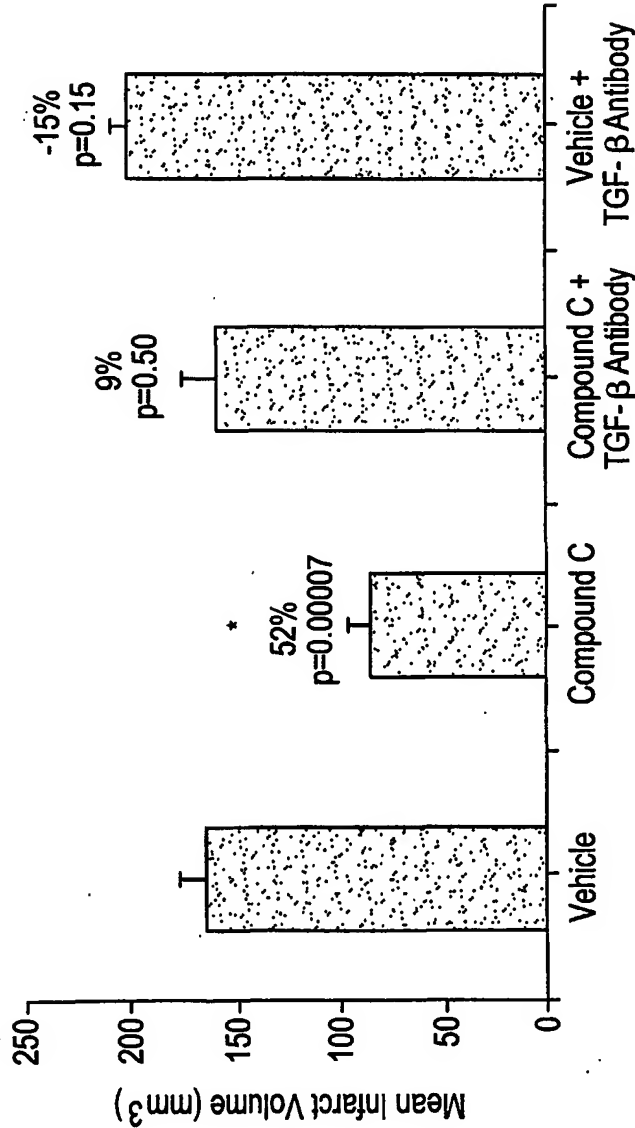
WO 02/057222

PCT/US02/01205

5/45

FIG. 5

TGF- β Neutralizing Antibody Blocks Neuroprotective
Effect of Compound C Against 2 hour MCAO

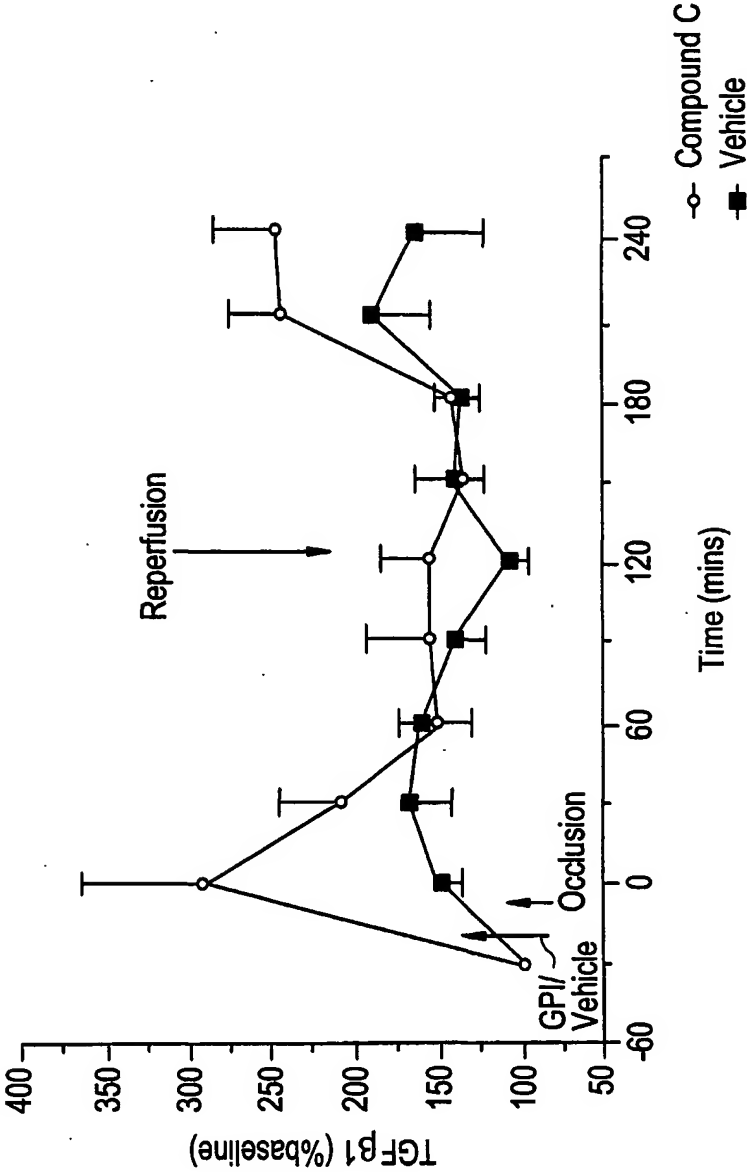


WO 02/057222

PCT/US02/01205

6/45

FIG. 6
TGF- β 1 in Dialysate from Rats Treated with Compound C
During Ischemia and Reperfusion



WO 02/057222

PCT/US02/01205

7/45
FIG. 7A

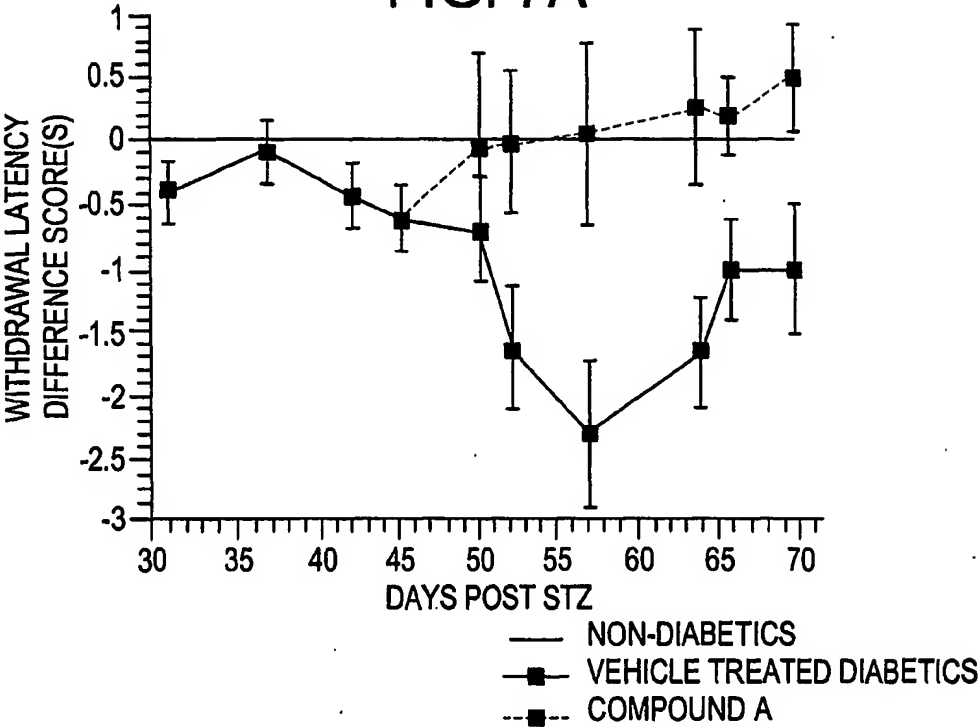
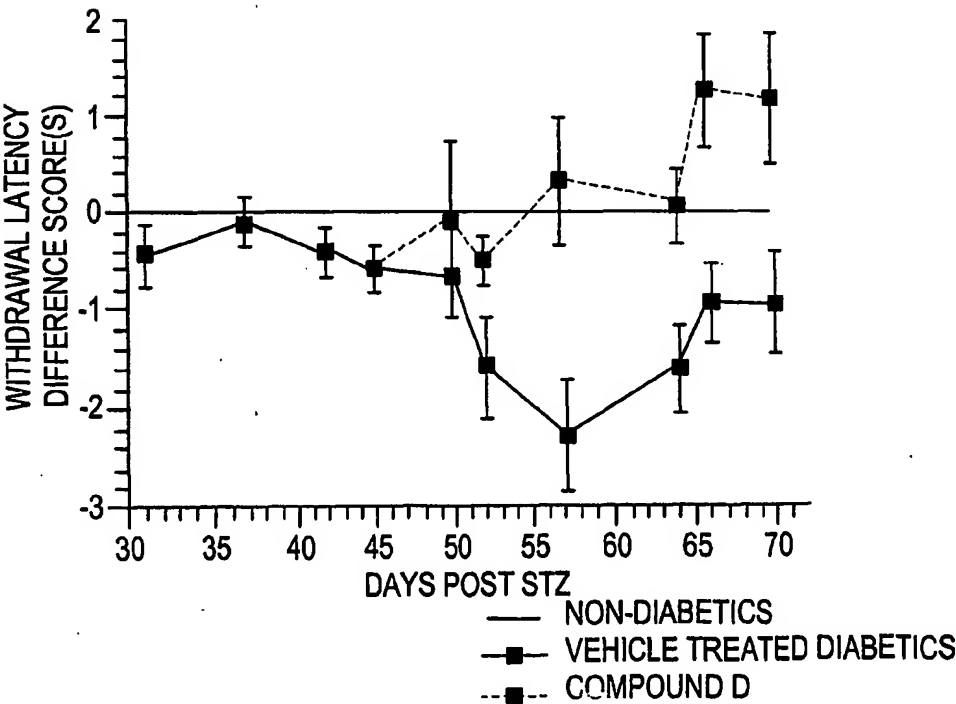


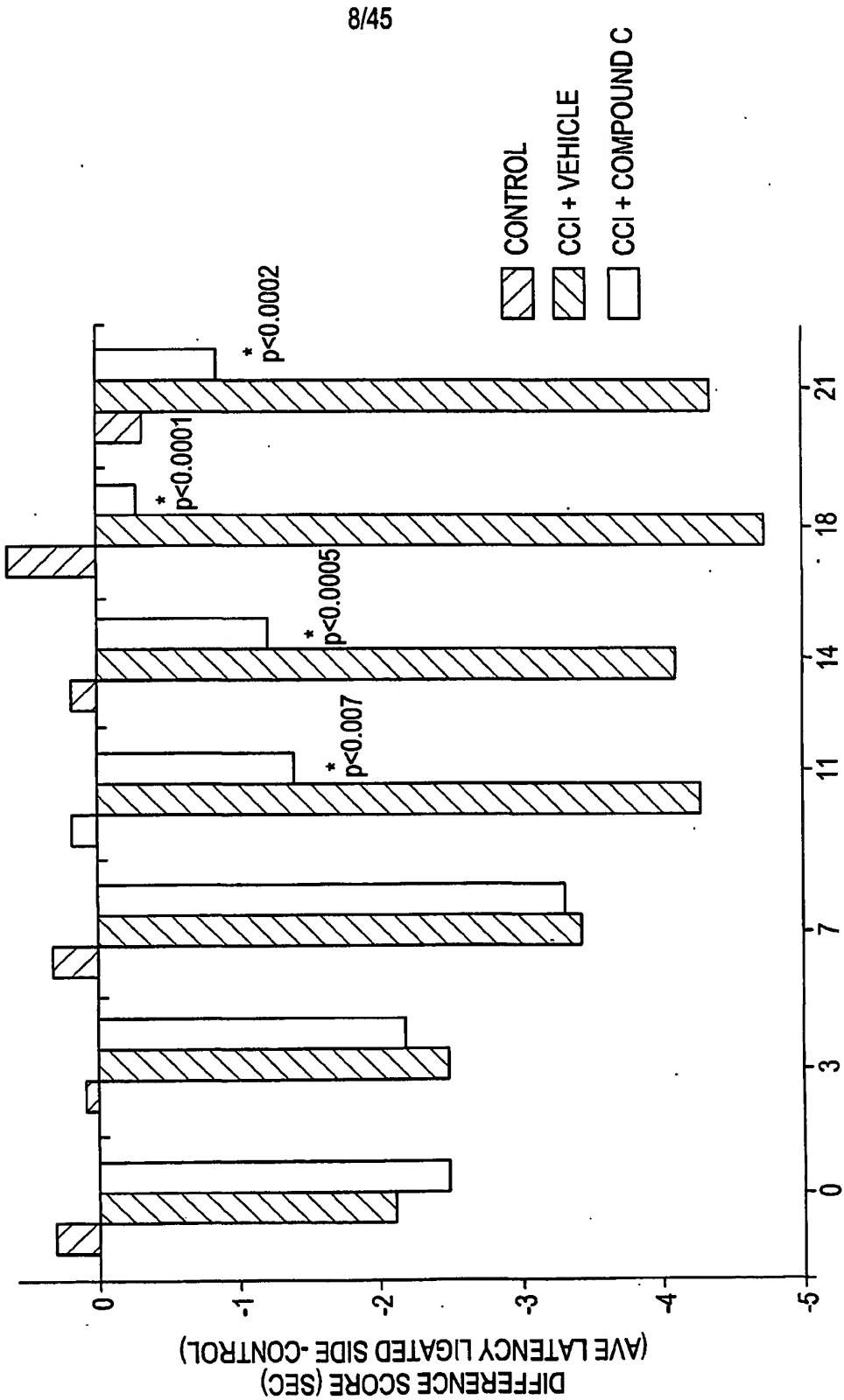
FIG. 7B



WO 02/057222

PCT/US02/01205

FIG. 8



WO 02/057222

PCT/US02/01205

9/45

FIG. 9A

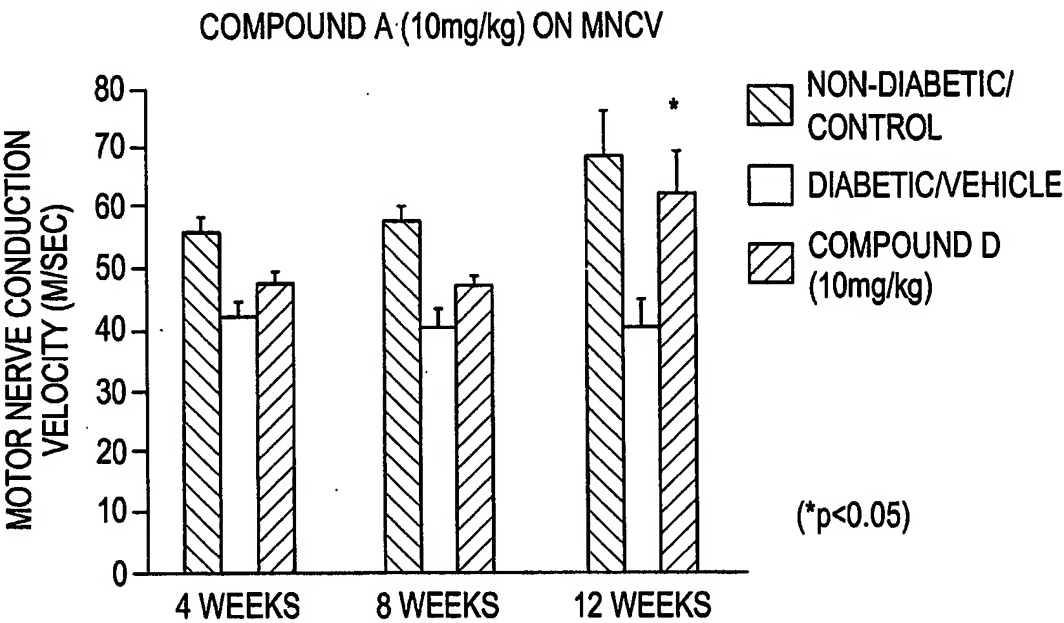
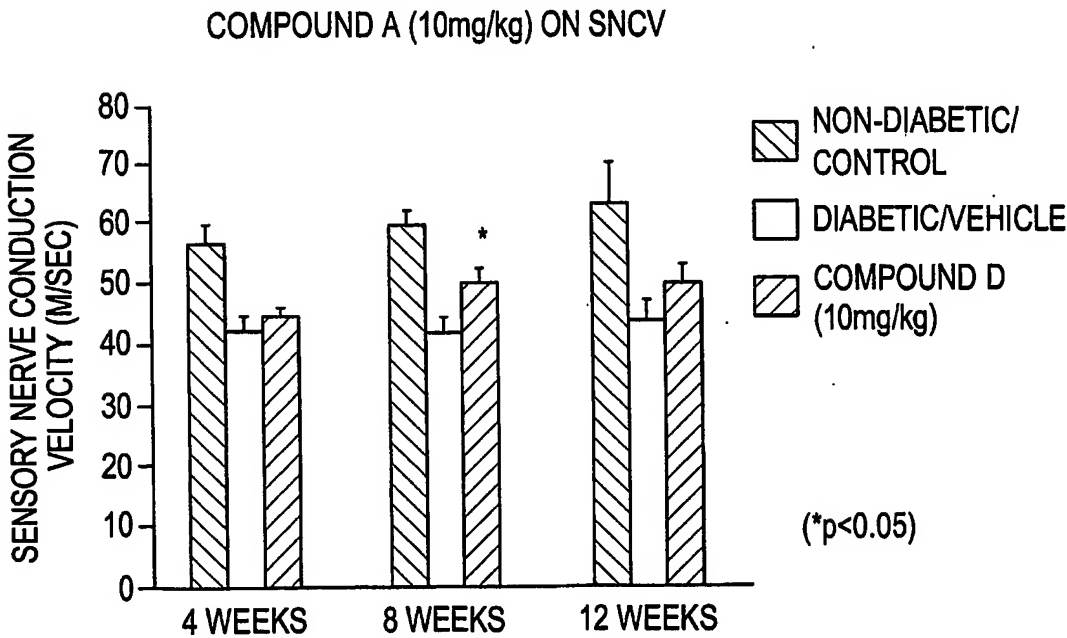


FIG. 9B



WO 02/057222

PCT/US02/01205

10/45

FIG. 10A

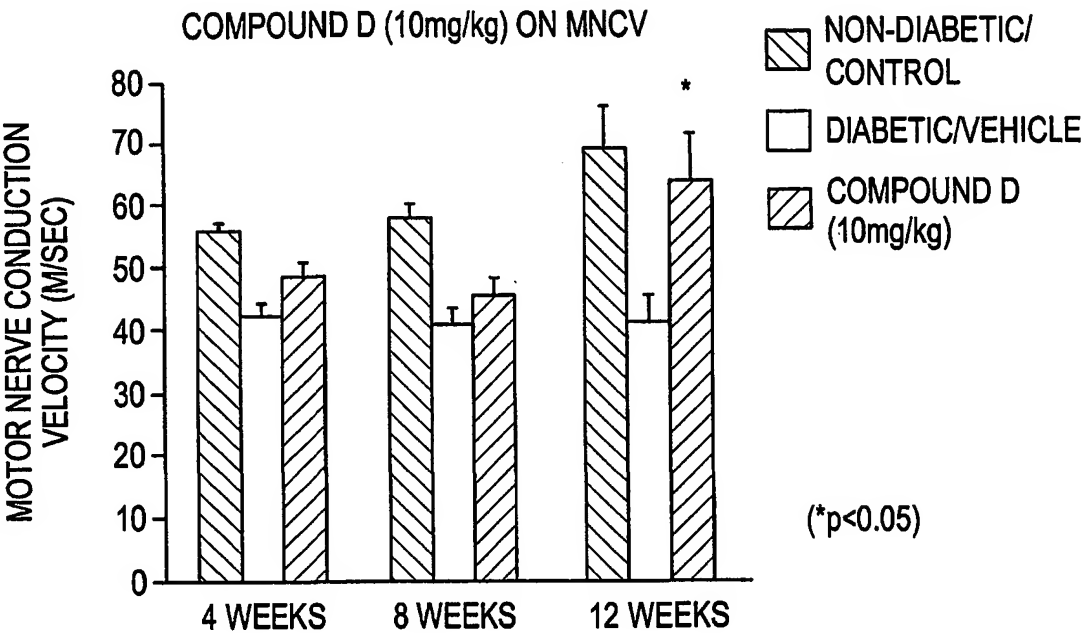
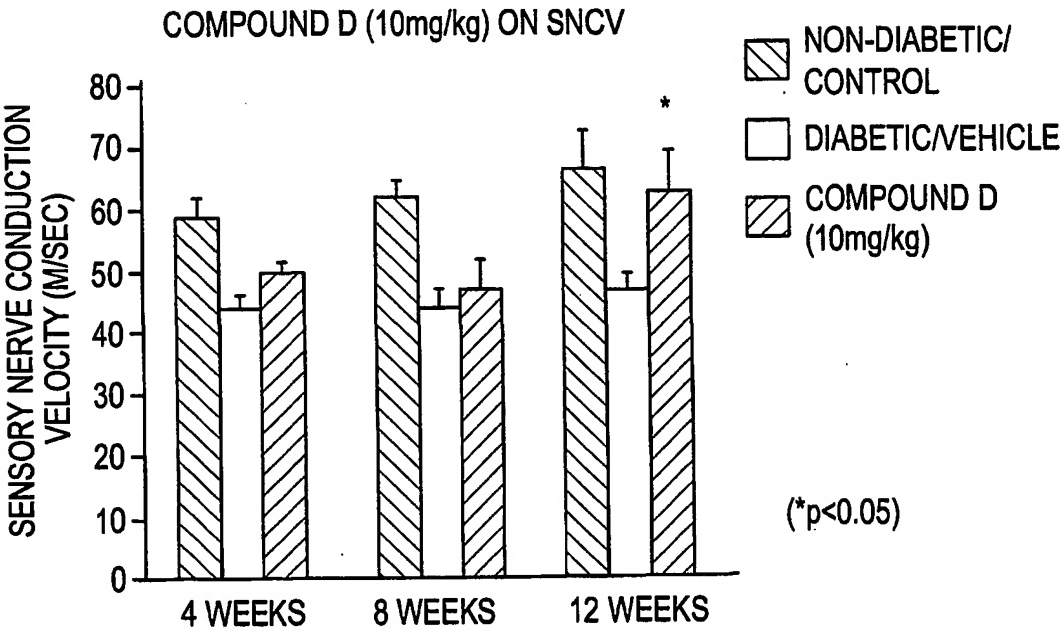


FIG. 10B

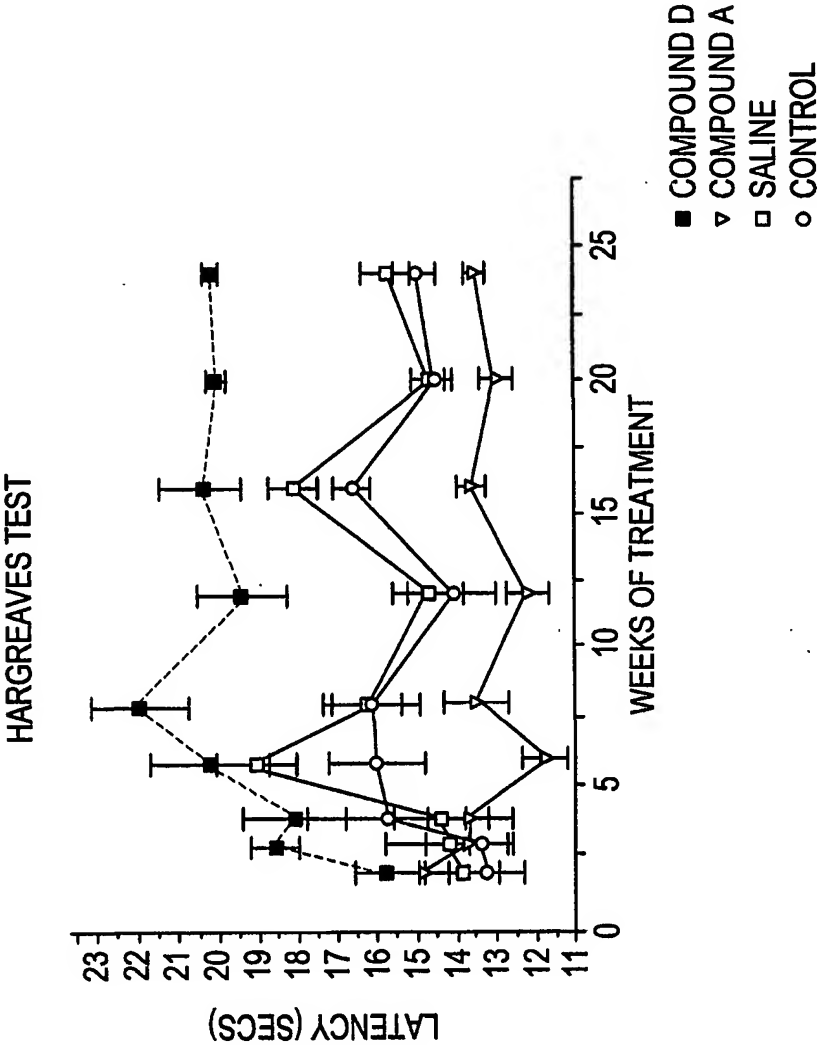


WO 02/057222

PCT/US02/01205

11/45

FIG. 11

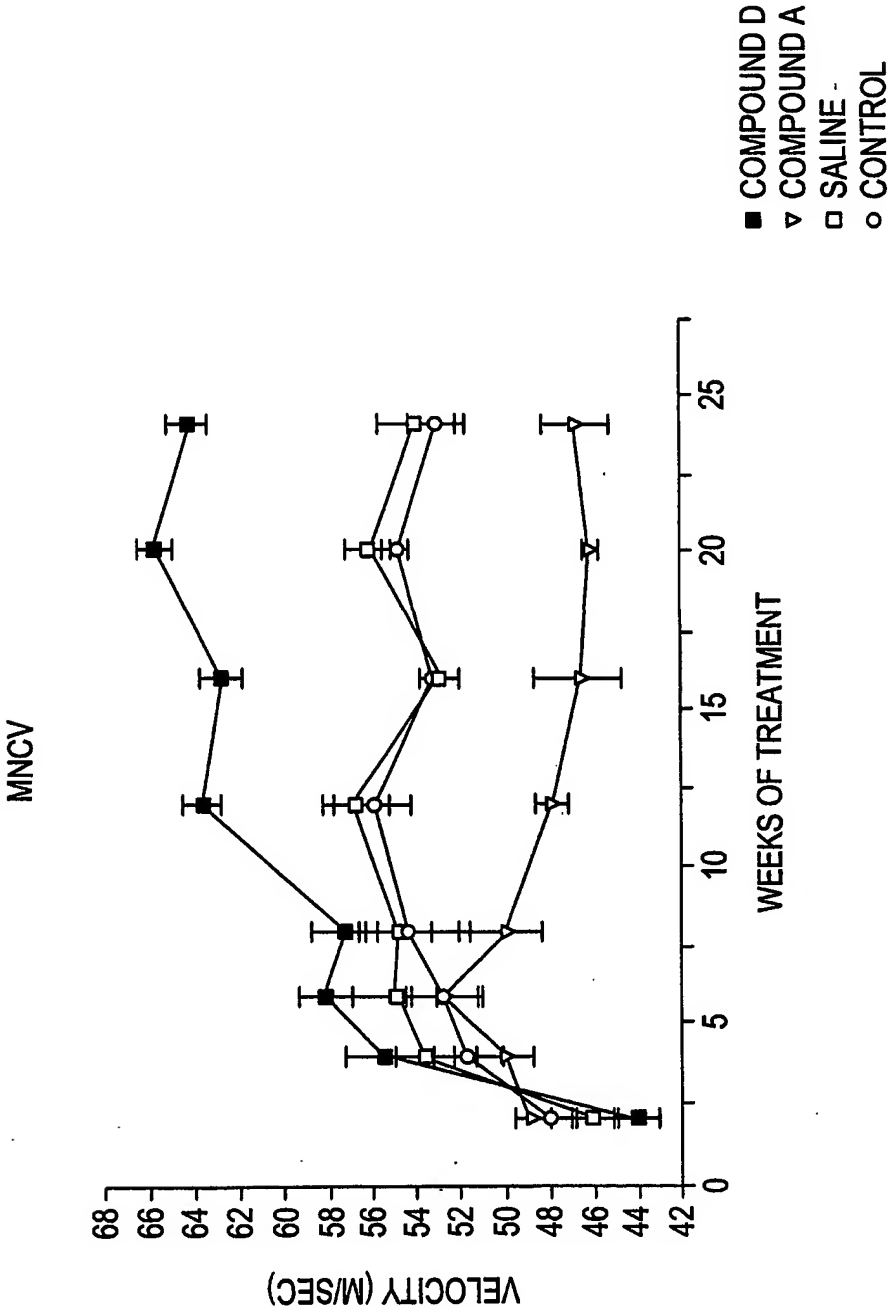


WO 02/057222

PCT/US02/01205

12/45

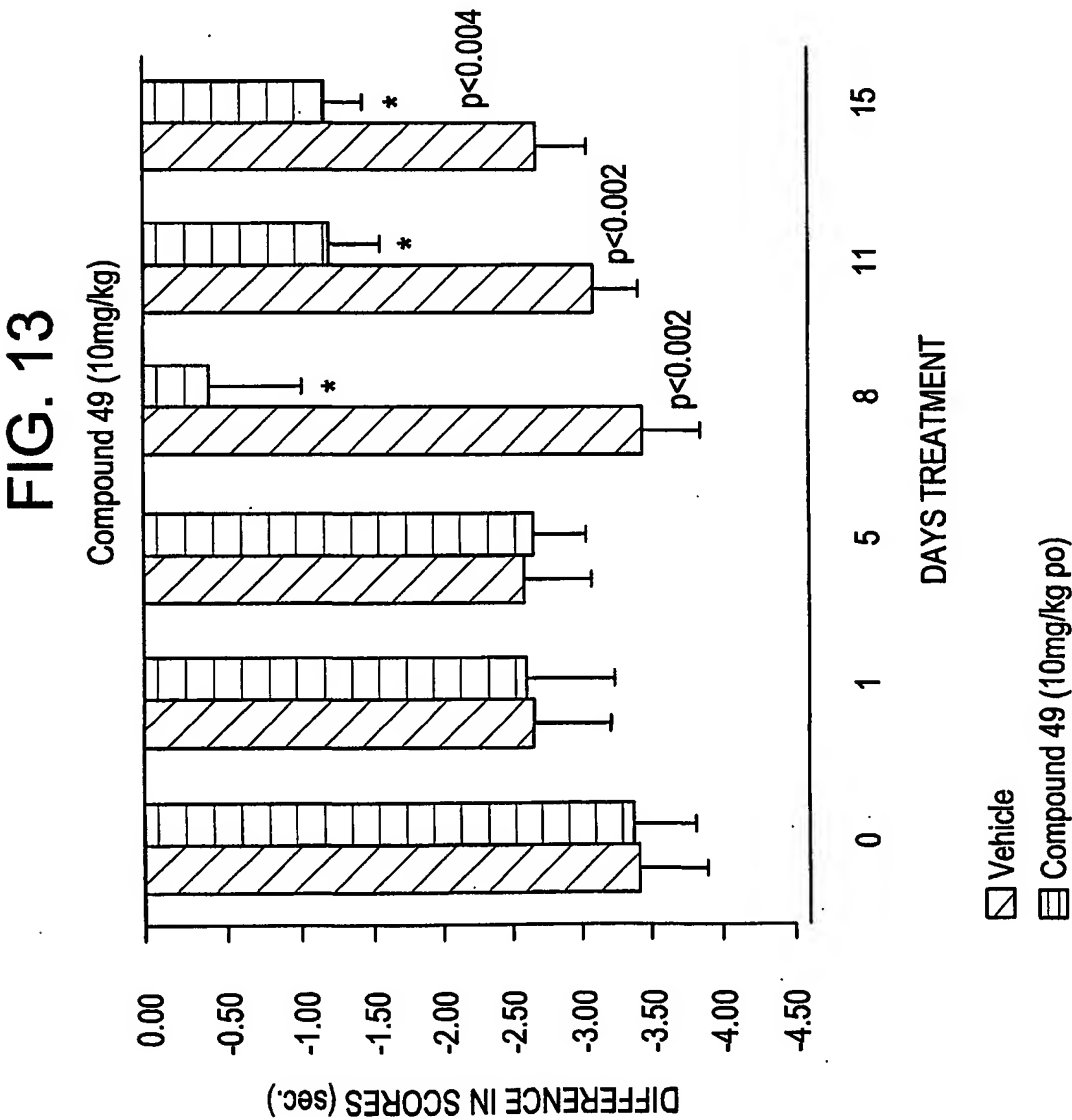
FIG. 12



WO 02/057222

PCT/US02/01205

13/45



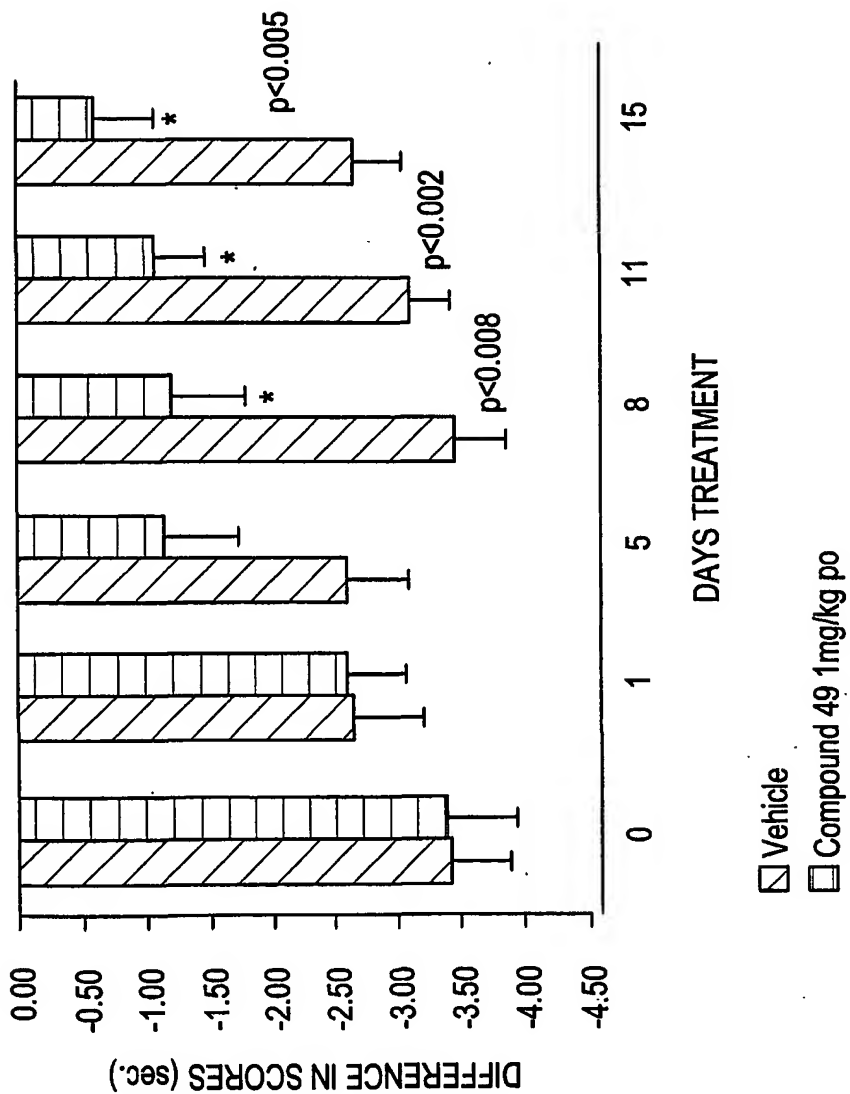
WO 02/057222

PCT/US02/01205

14/45

FIG. 14

Compound 49 (1mg/kg)

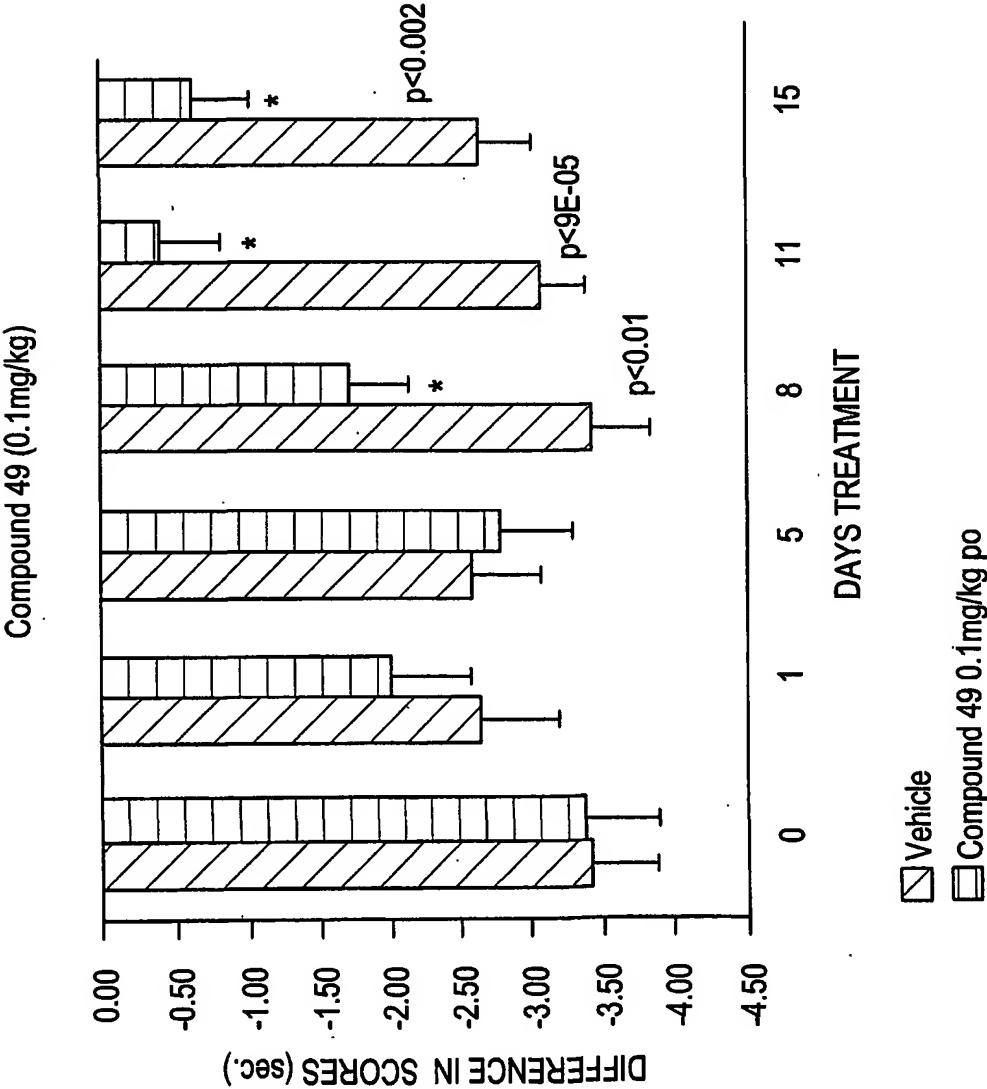


WO 02/057222

PCT/US02/01205

15/45

FIG. 15

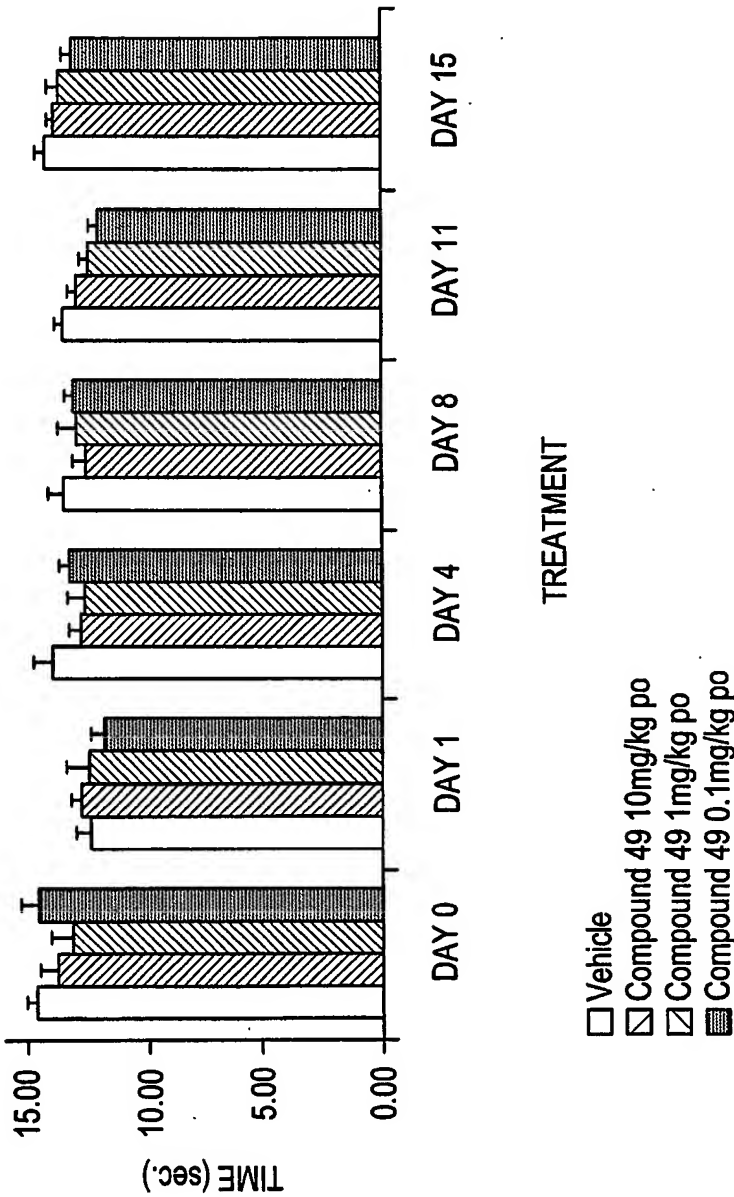


WO 02/057222

PCT/US02/01205

16/45

FIG. 16
LATENCY ON THE SHAM SIDE
(Compound 49)

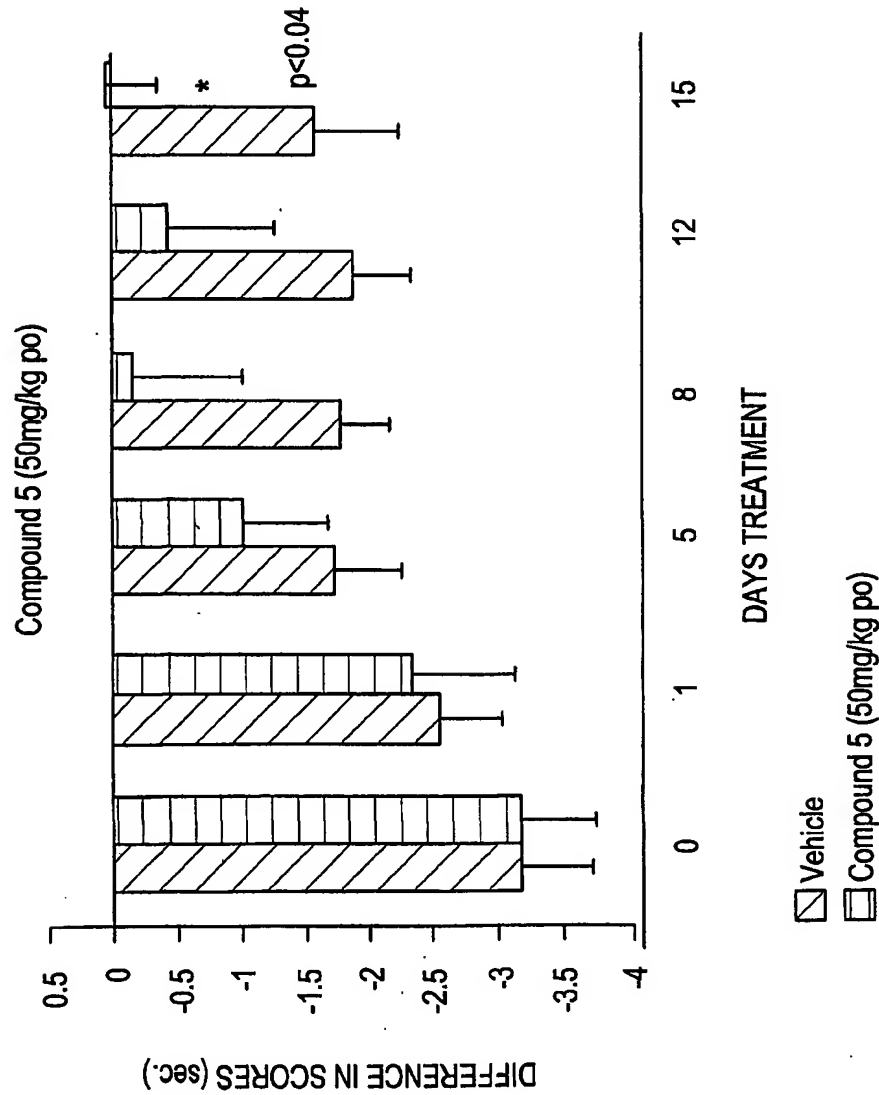


WO 02/057222

PCT/US02/01205

17/45

FIG. 17

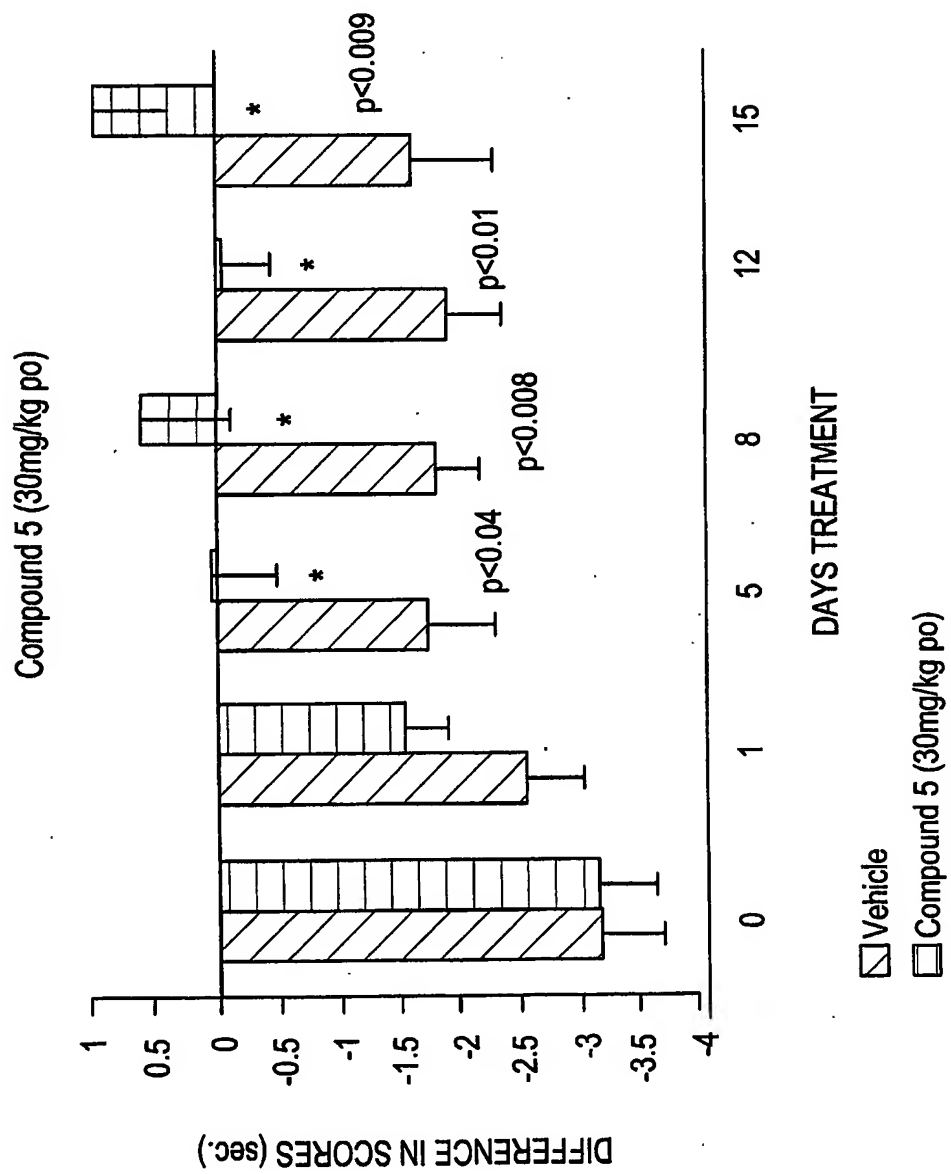


WO 02/057222

PCT/US02/01205

18/45

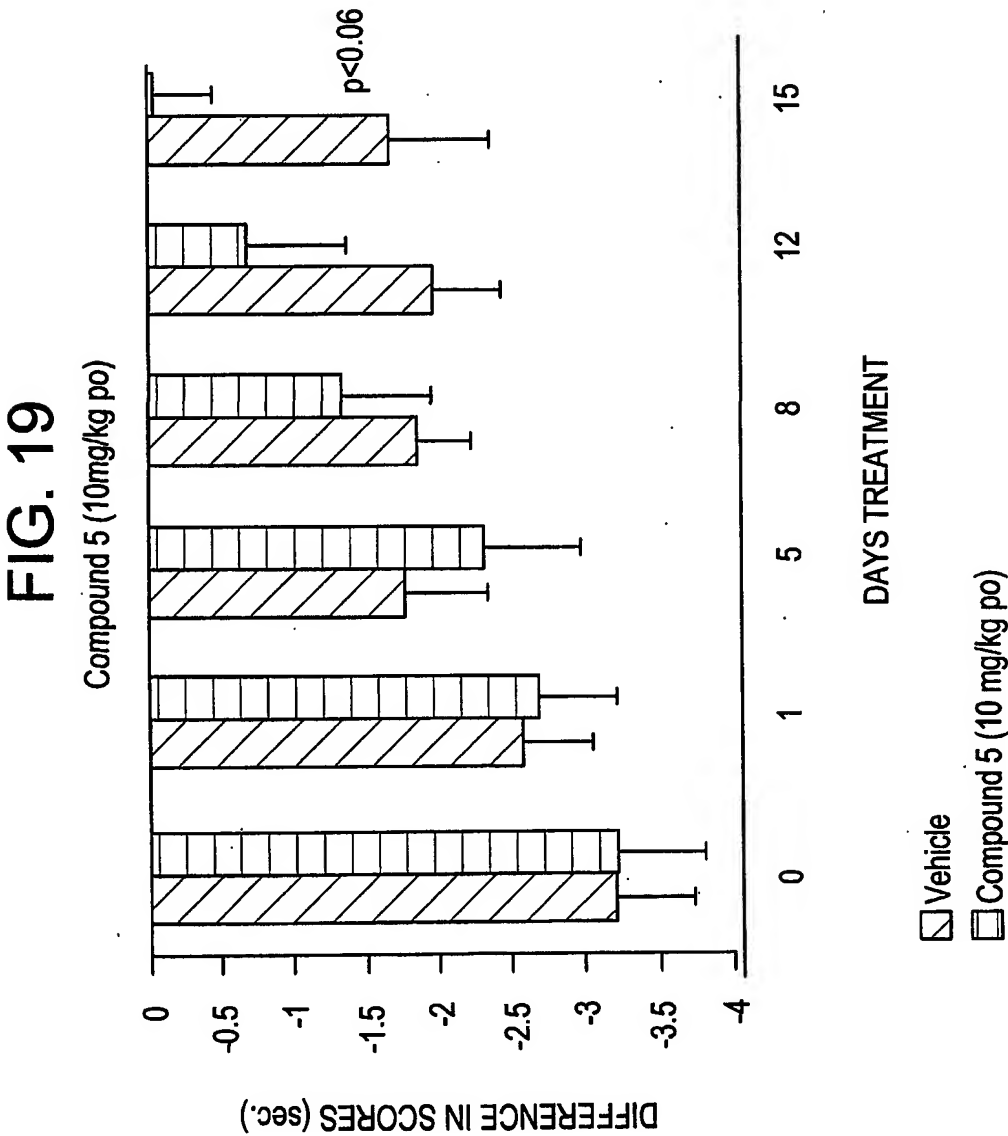
FIG. 18



WO 02/057222

PCT/US02/01205

19/45



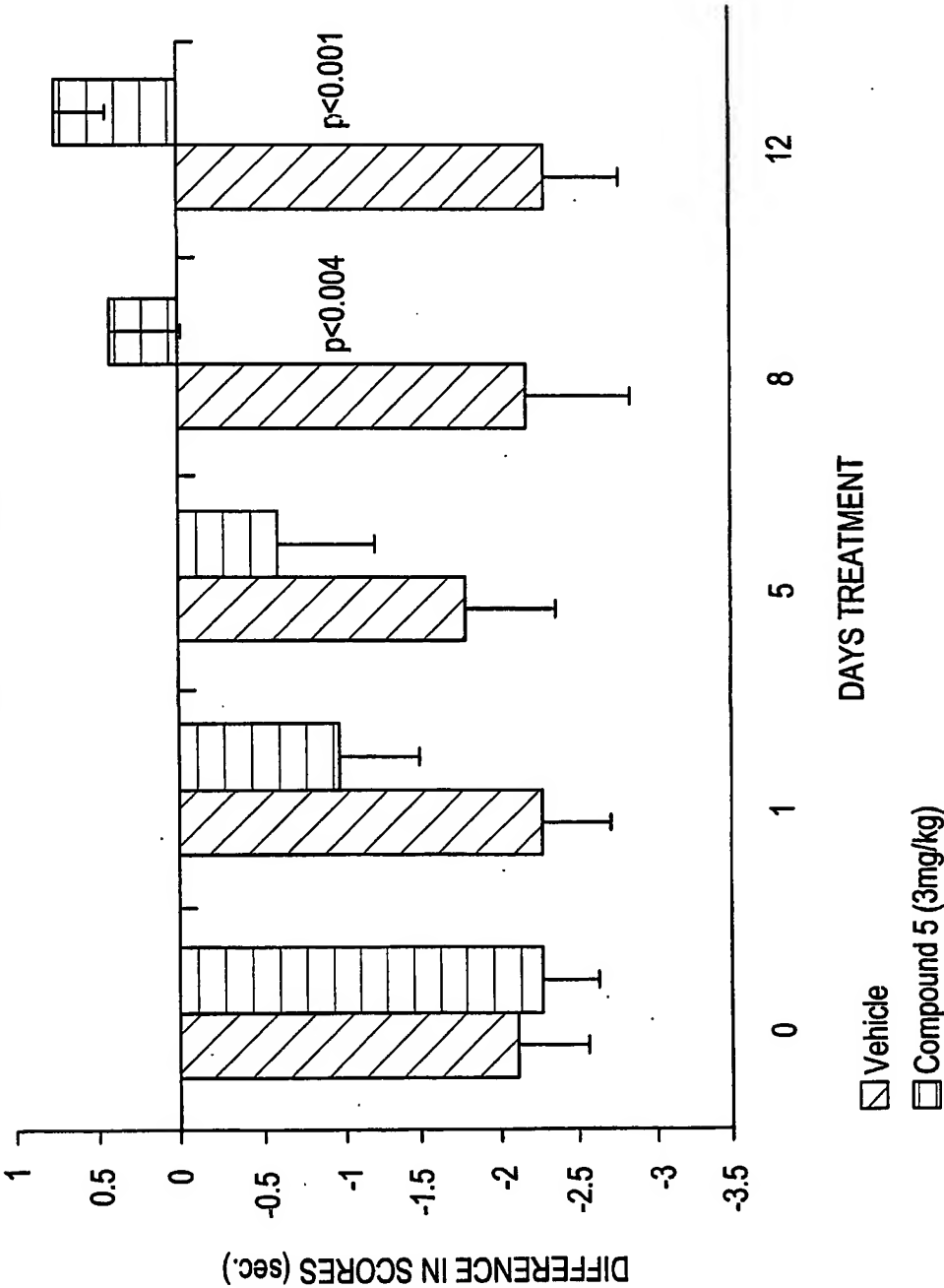
WO 02/057222

PCT/US02/01205

20/45

FIG. 20

Compound 5 (3mg/kg)



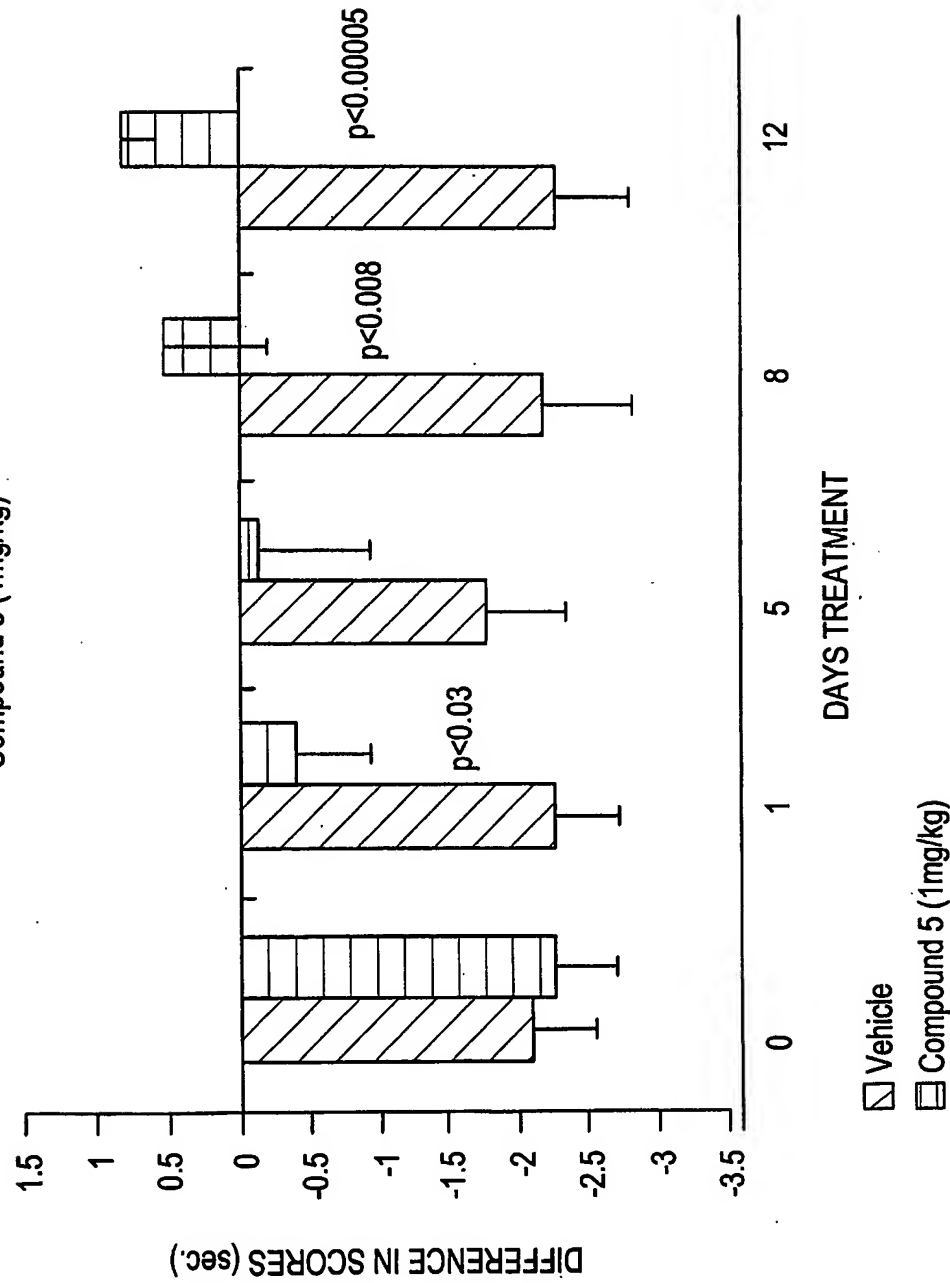
WO 02/057222

PCT/US02/01205

21/45

FIG. 21

Compound 5 (1mg/kg)

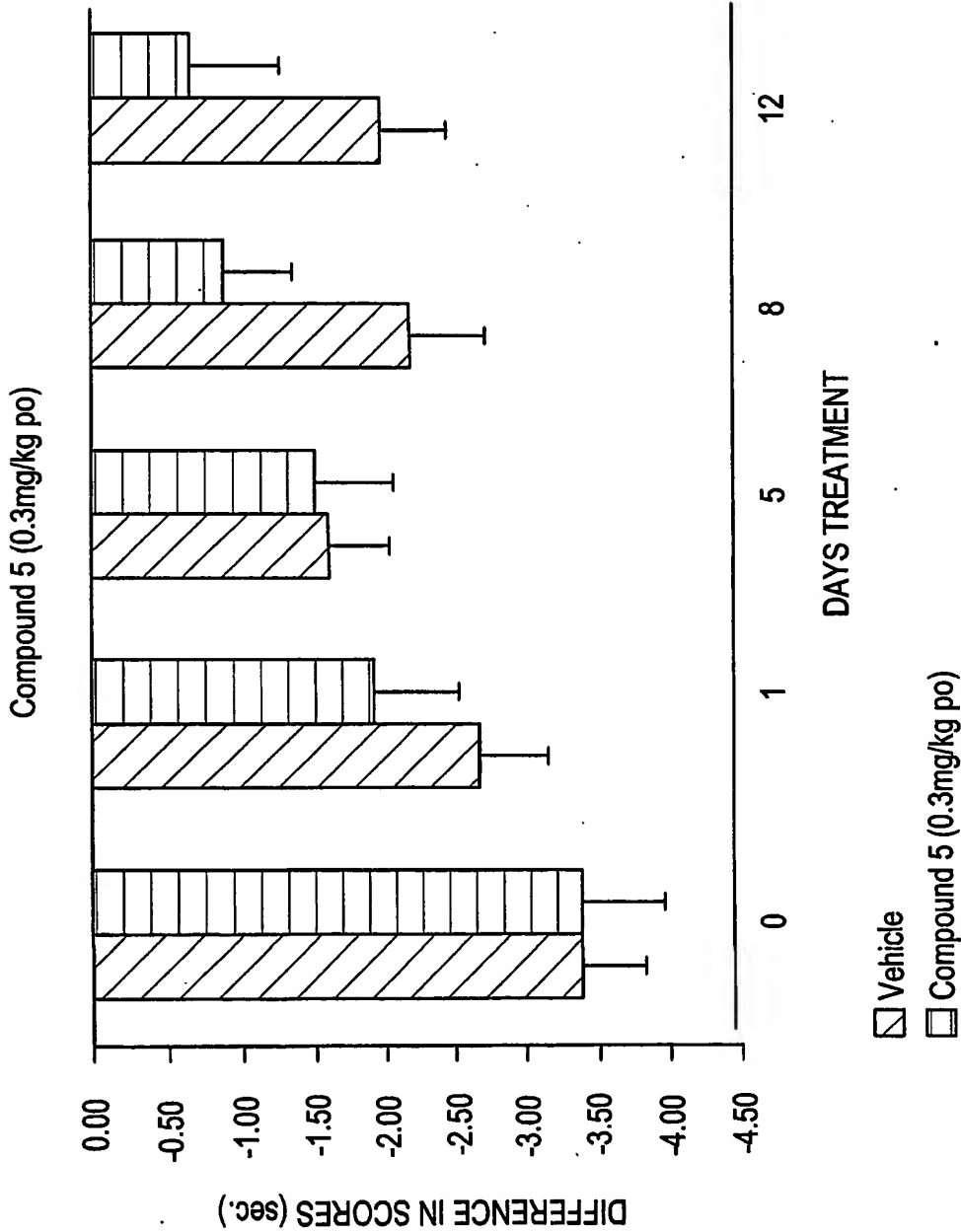


WO 02/057222

PCT/US02/01205

22/45

FIG. 22

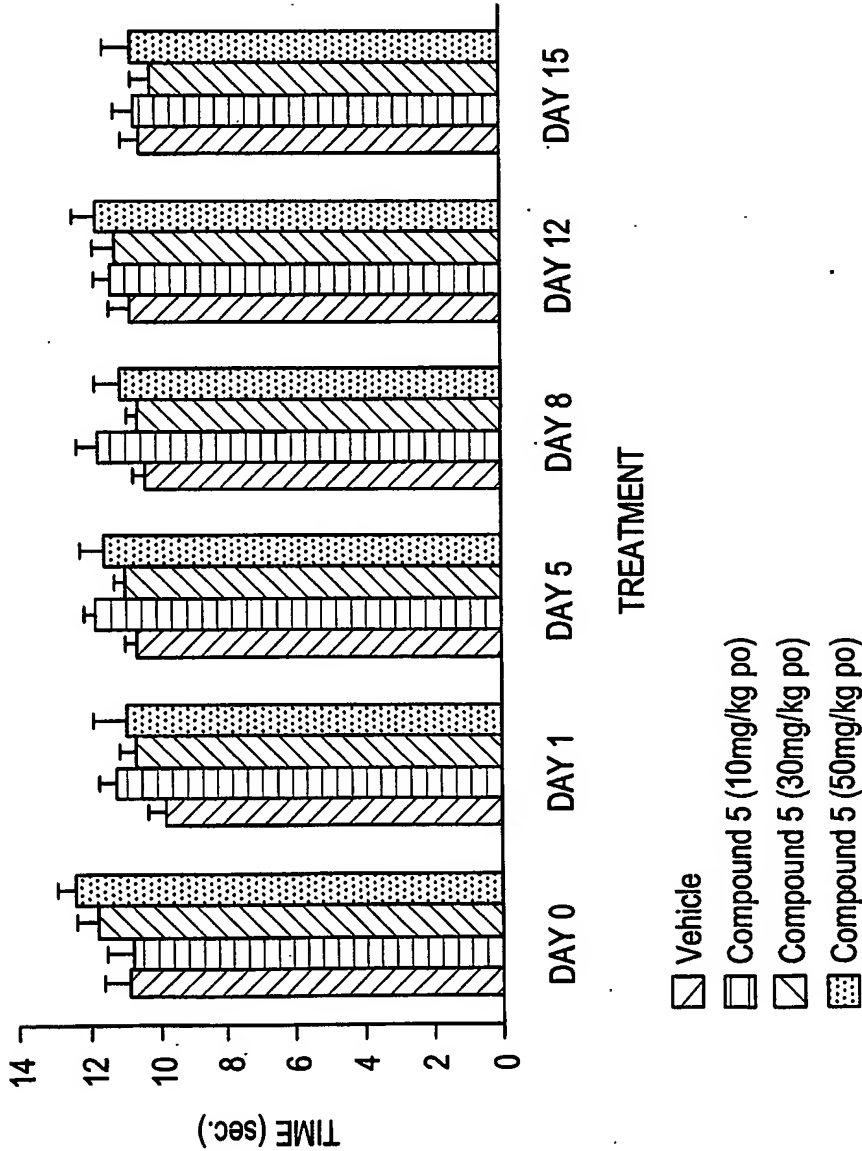


WO 02/057222

PCT/US02/01205

23/45

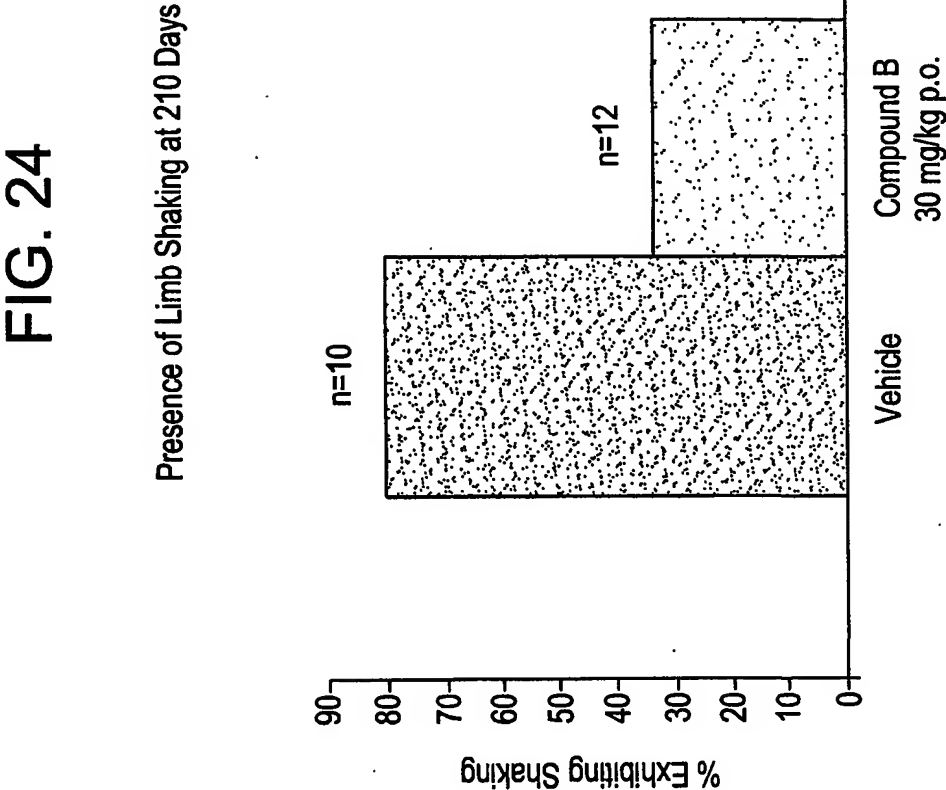
FIG. 23
LATENCY ON THE SHAM SIDE



WO 02/057222

PCT/US02/01205

24/45



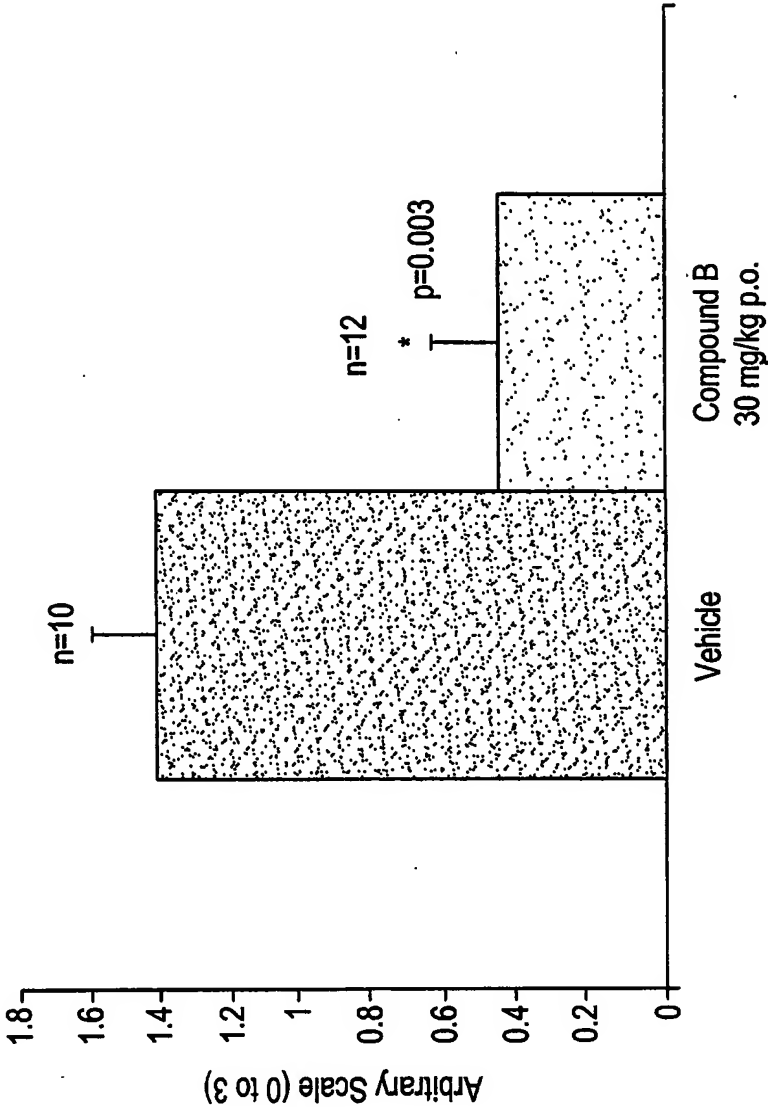
WO 02/057222

PCT/US02/01205

25/45

FIG. 25

Gait in SOD Transgenic Mice at 210 Days

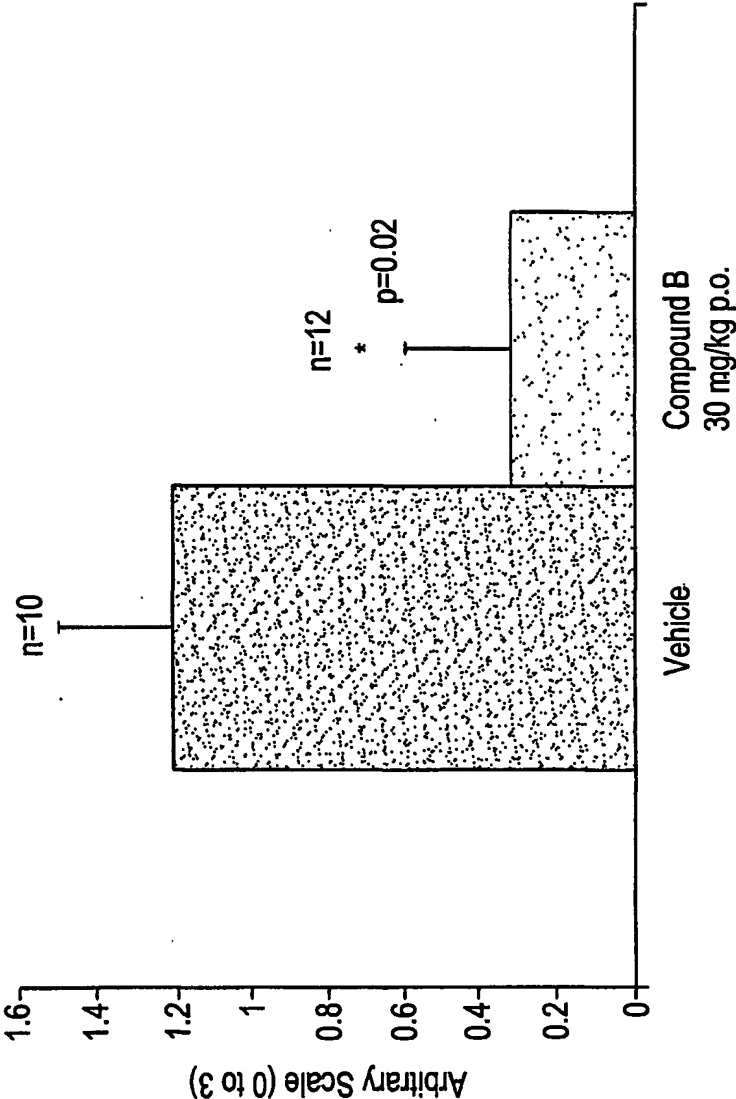


WO 02/057222

PCT/US02/01205

26/45

FIG. 26
Dragging Hind Limbs in SOD
Transgenic Mice at 210 Days



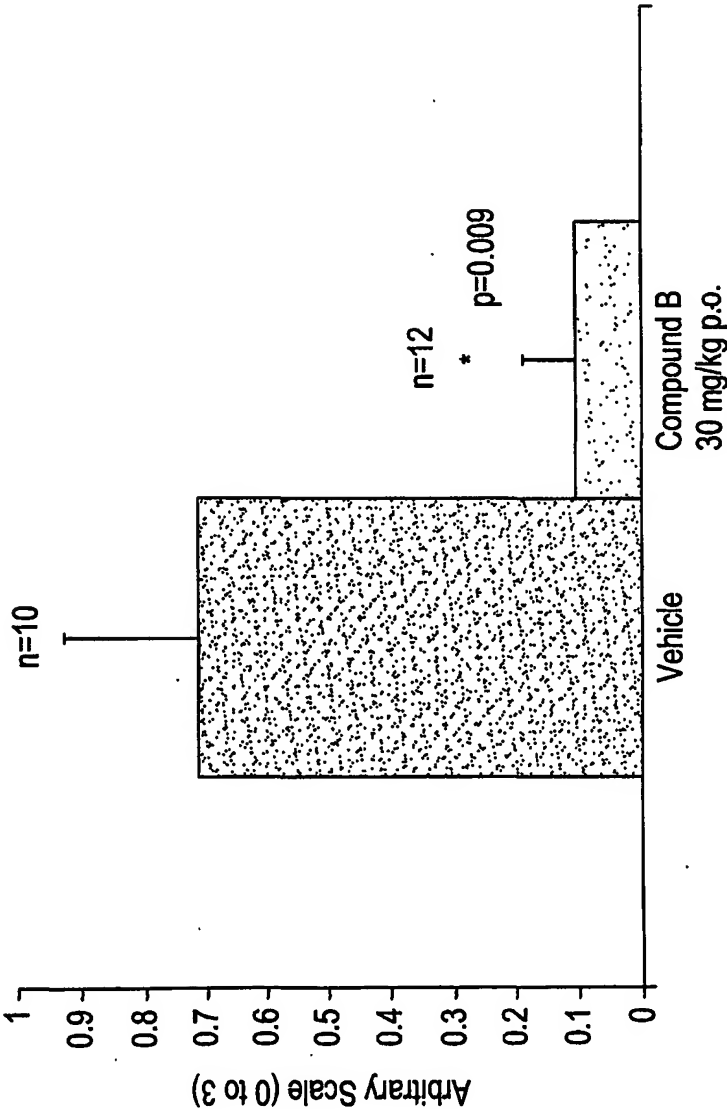
WO 02/057222

PCT/US02/01205

27/45

FIG. 27

Crossing of Limbs in SOD
Transgenic Mice at 210 Days

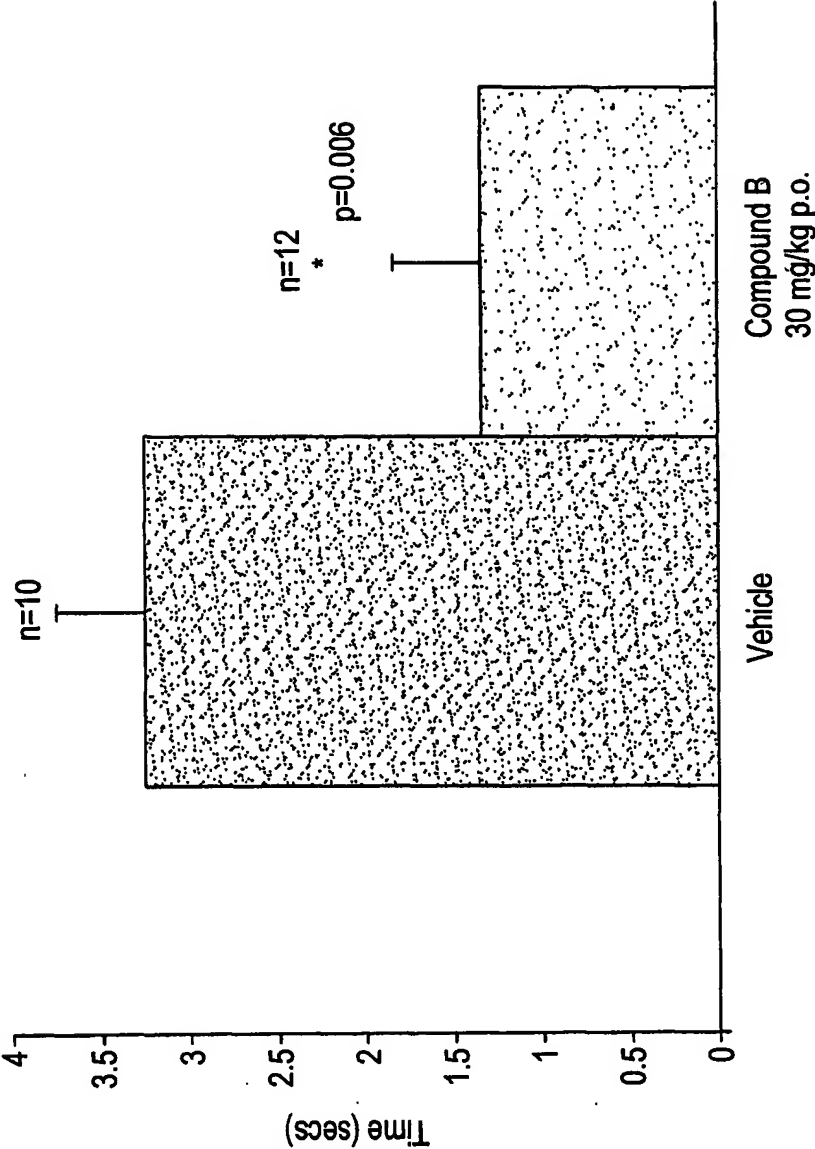


WO 02/057222

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28/45

FIG. 28
Righting Reflex in SOD
Transgenic Mice at 210 Days

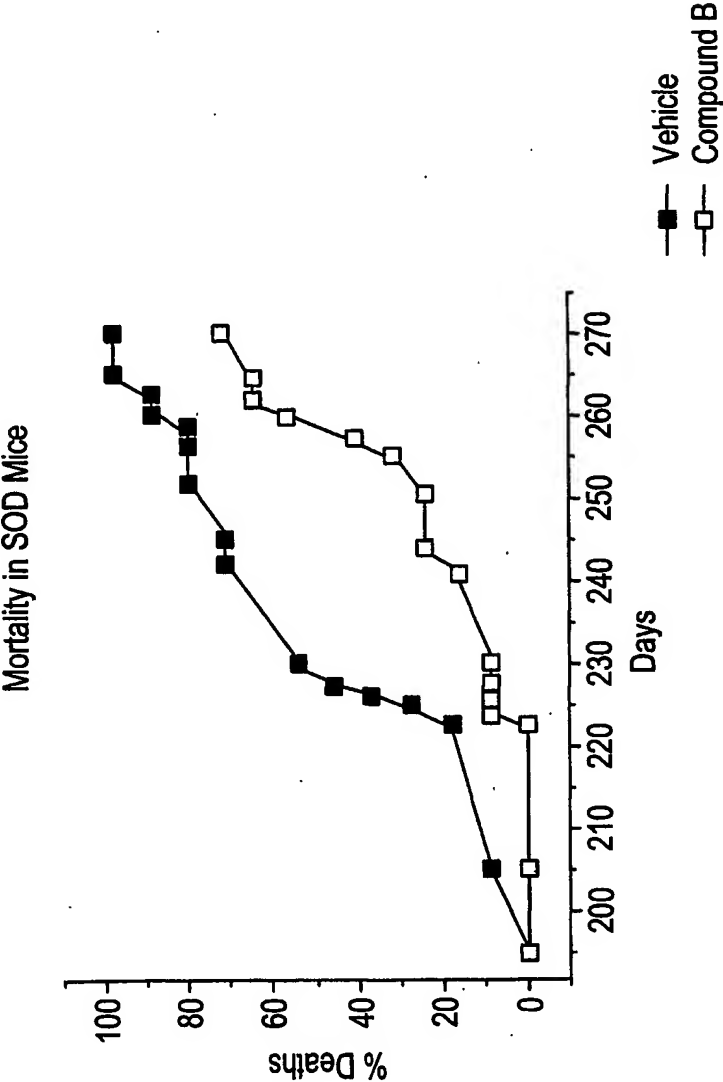


WO 02/057222

PCT/US02/01205

29/45

FIG. 29



WO 02/057222

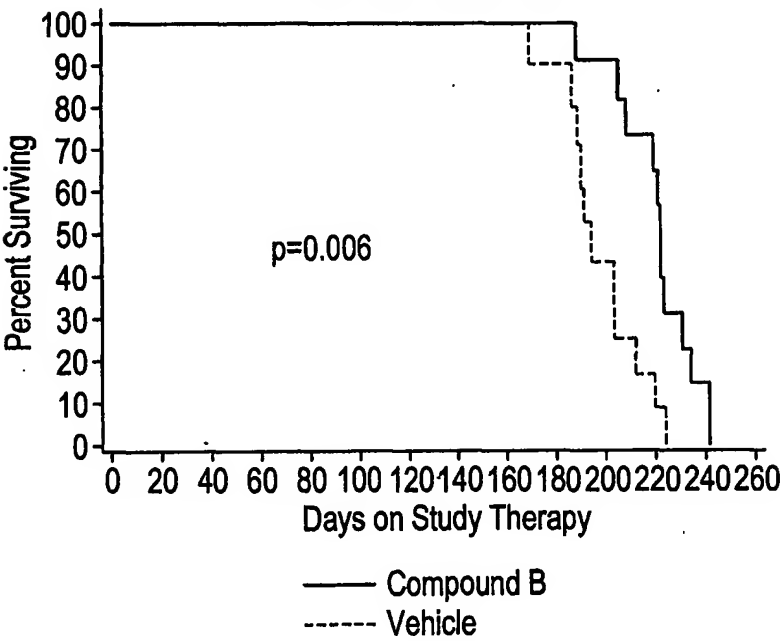
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30/45

FIG. 30

Kaplan-Meier Survival Curve of Mice After
Treatment with Compound B and Vehicle

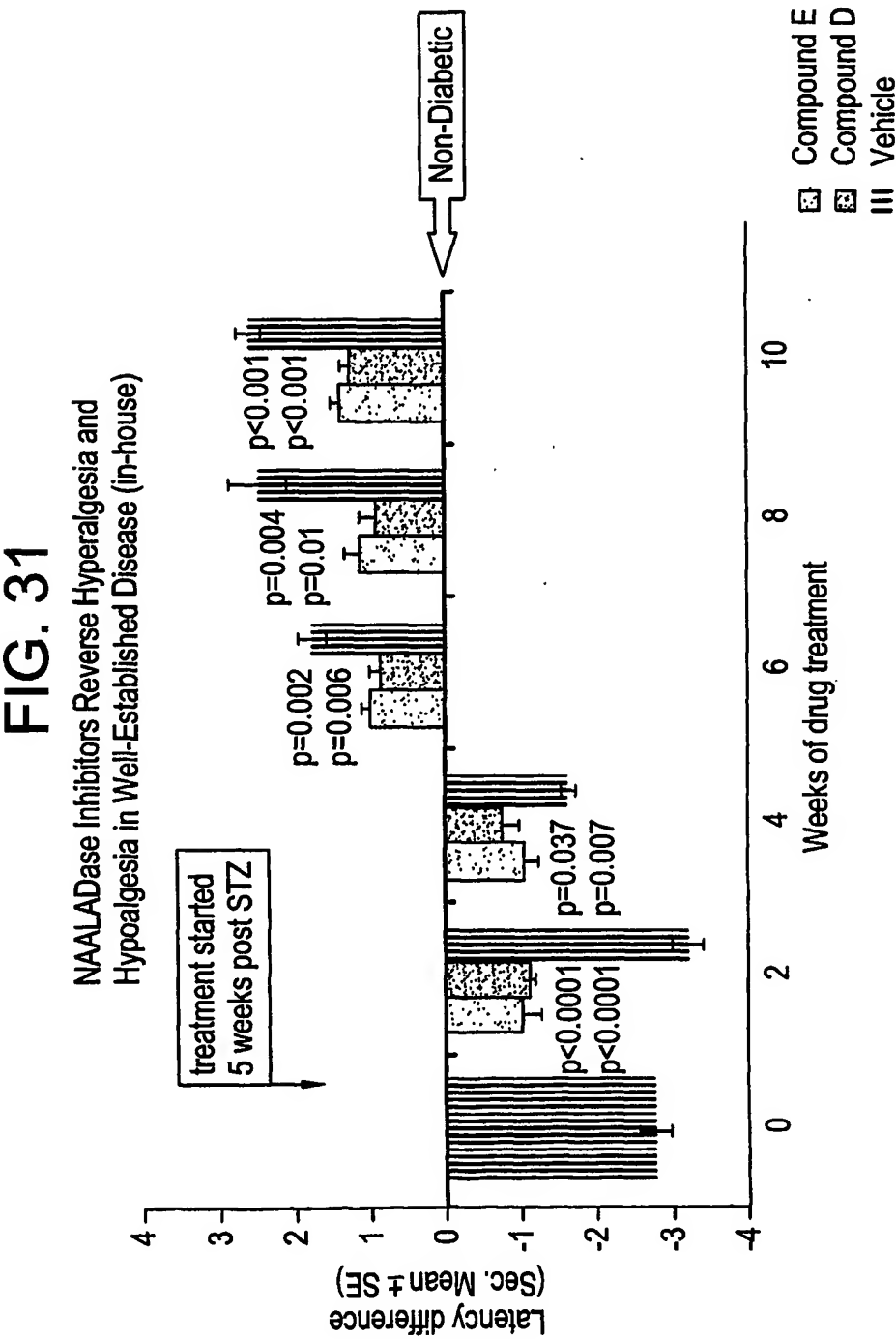
NAALADASE: ALS STUDY
OVERALL SURVIVAL



WO 02/057222

PCT/US02/01205

31/45

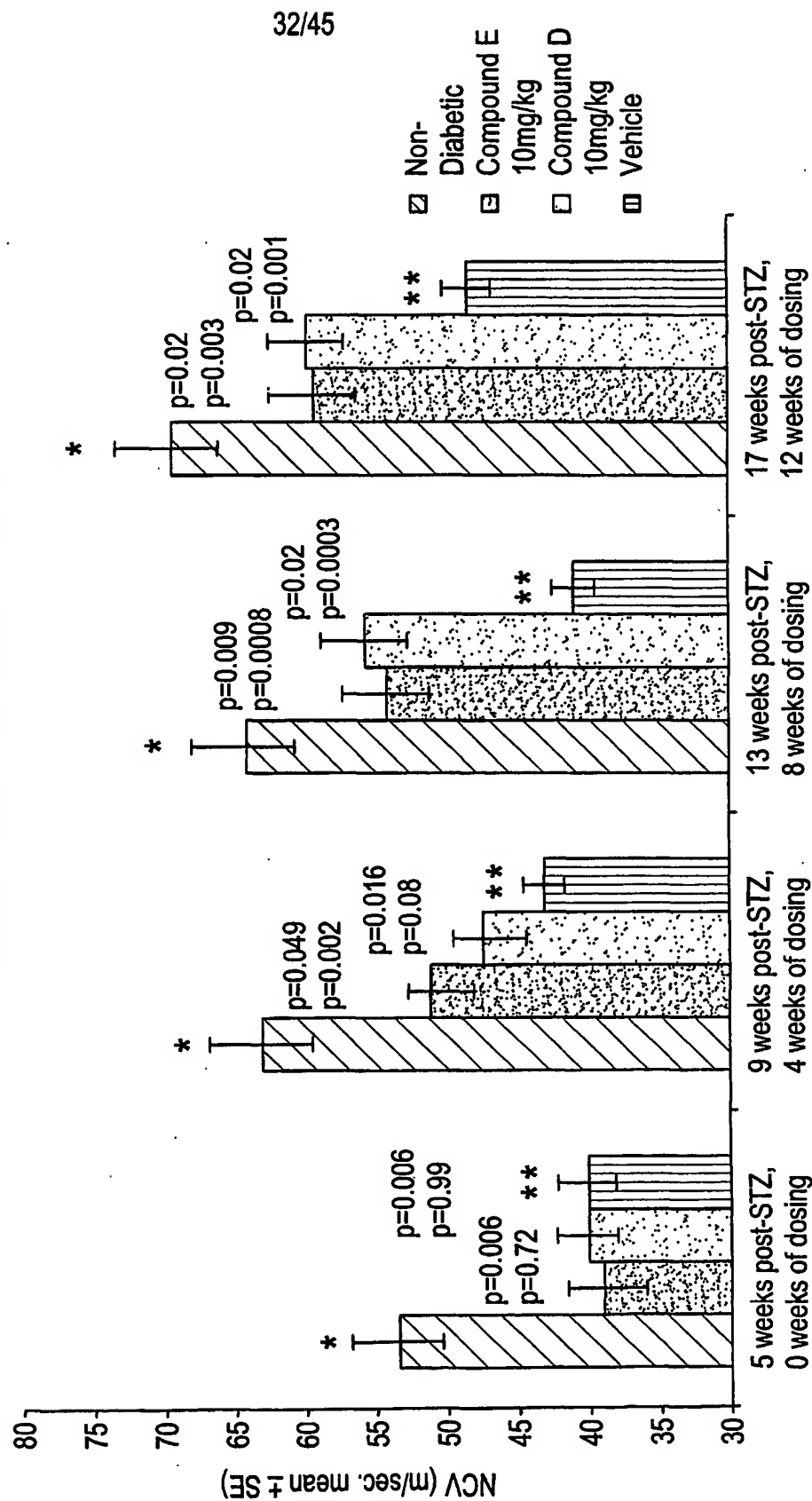


WO 02/057222

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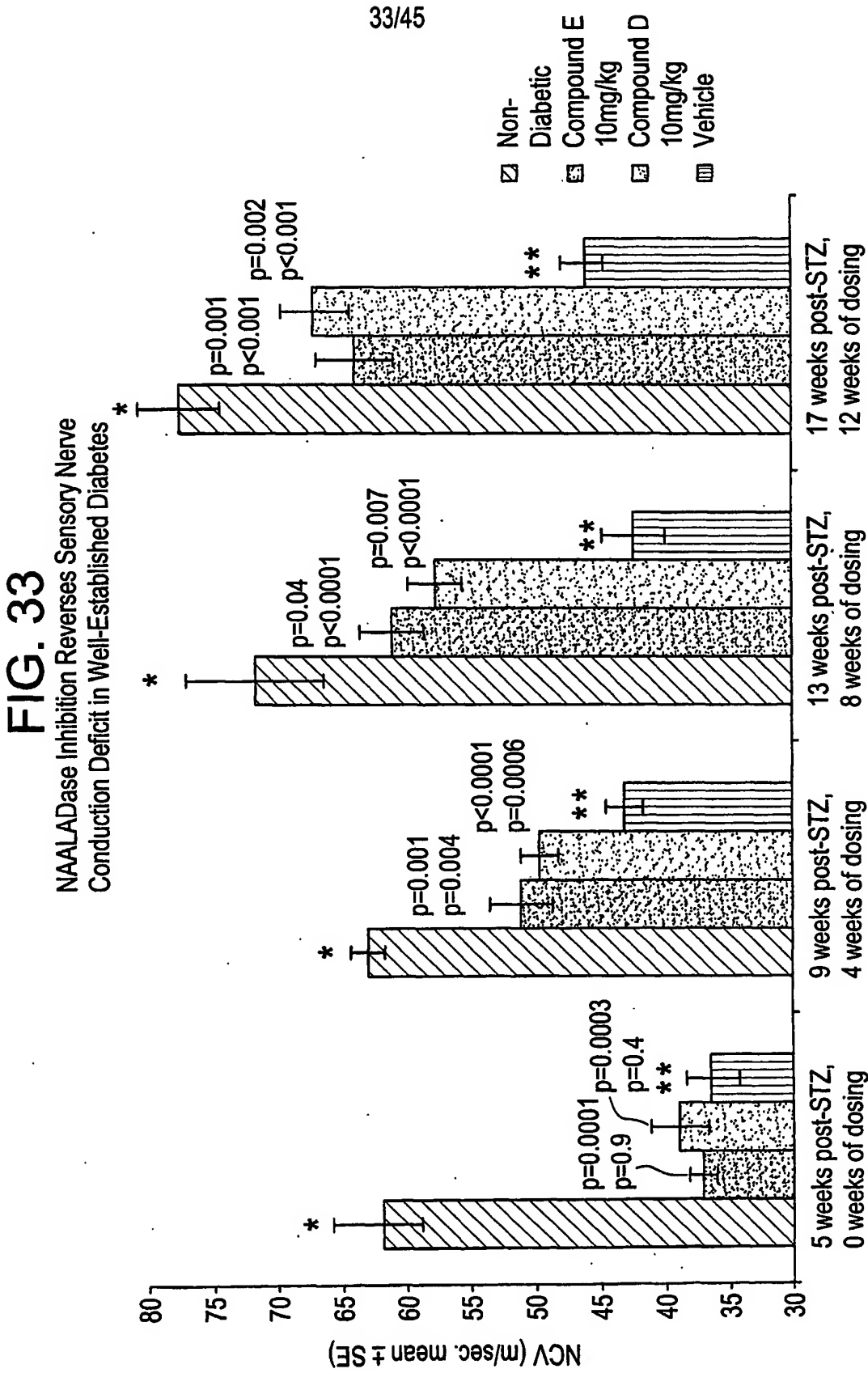
FIG. 32

NAALADase Inhibition Reverses Motor Nerve
Conduction Deficit in Well-Established Diabetes



WO 02/057222

PCT/US02/01205

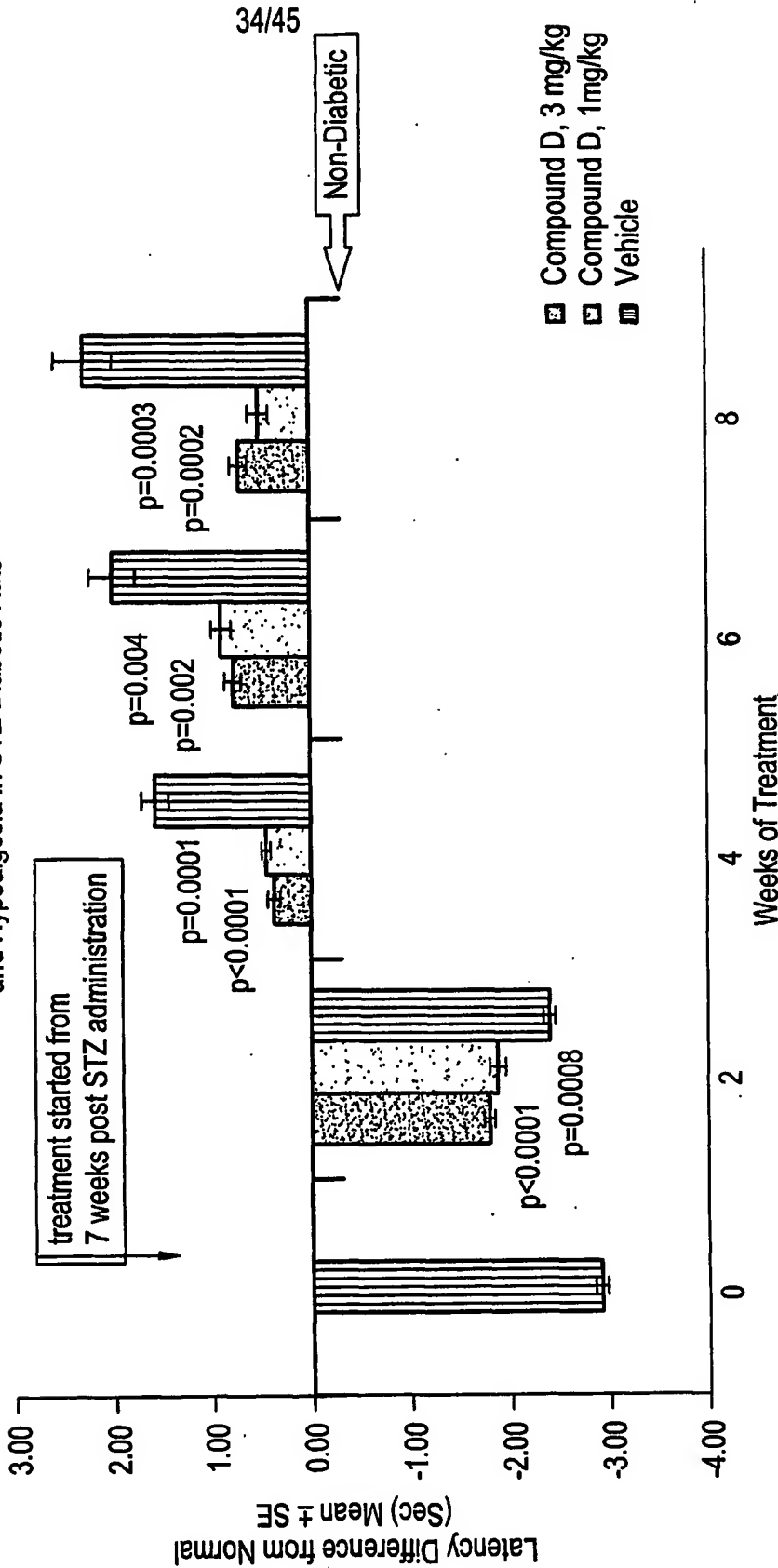


WO 02/057222

PCT/US02/01205

FIG. 34

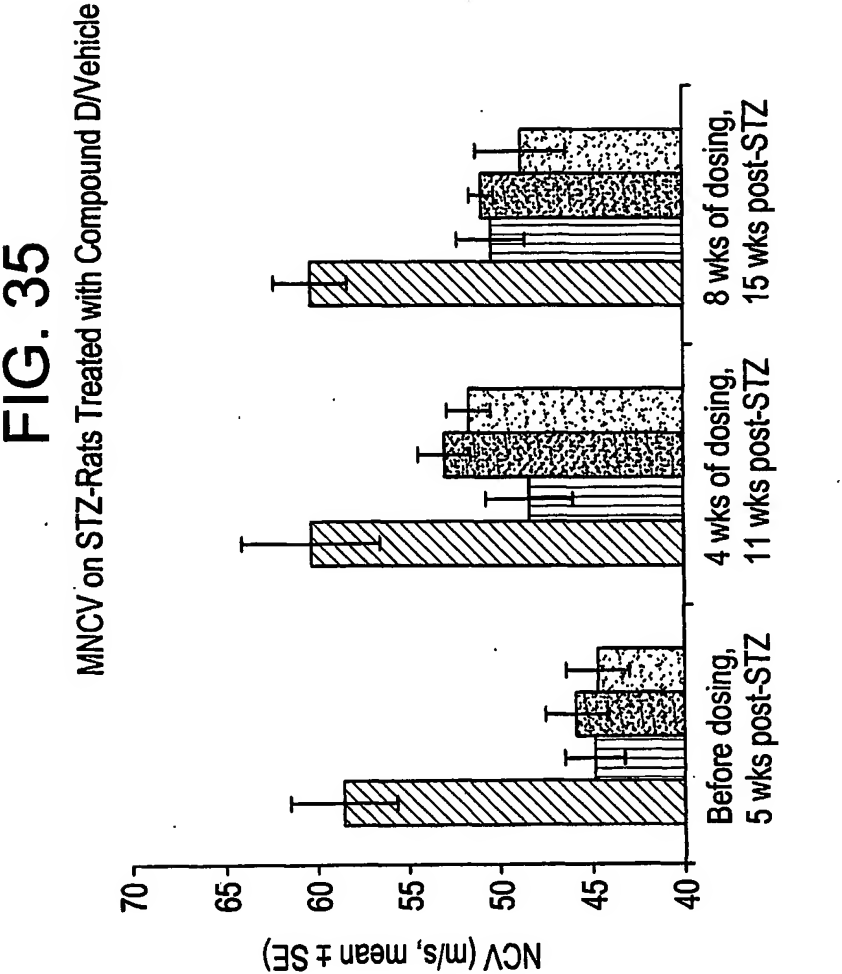
NAALADase Inhibition Attenuates Both Hyper-
and Hypoalgesia in STZ-Diabetic Rats



WO 02/057222

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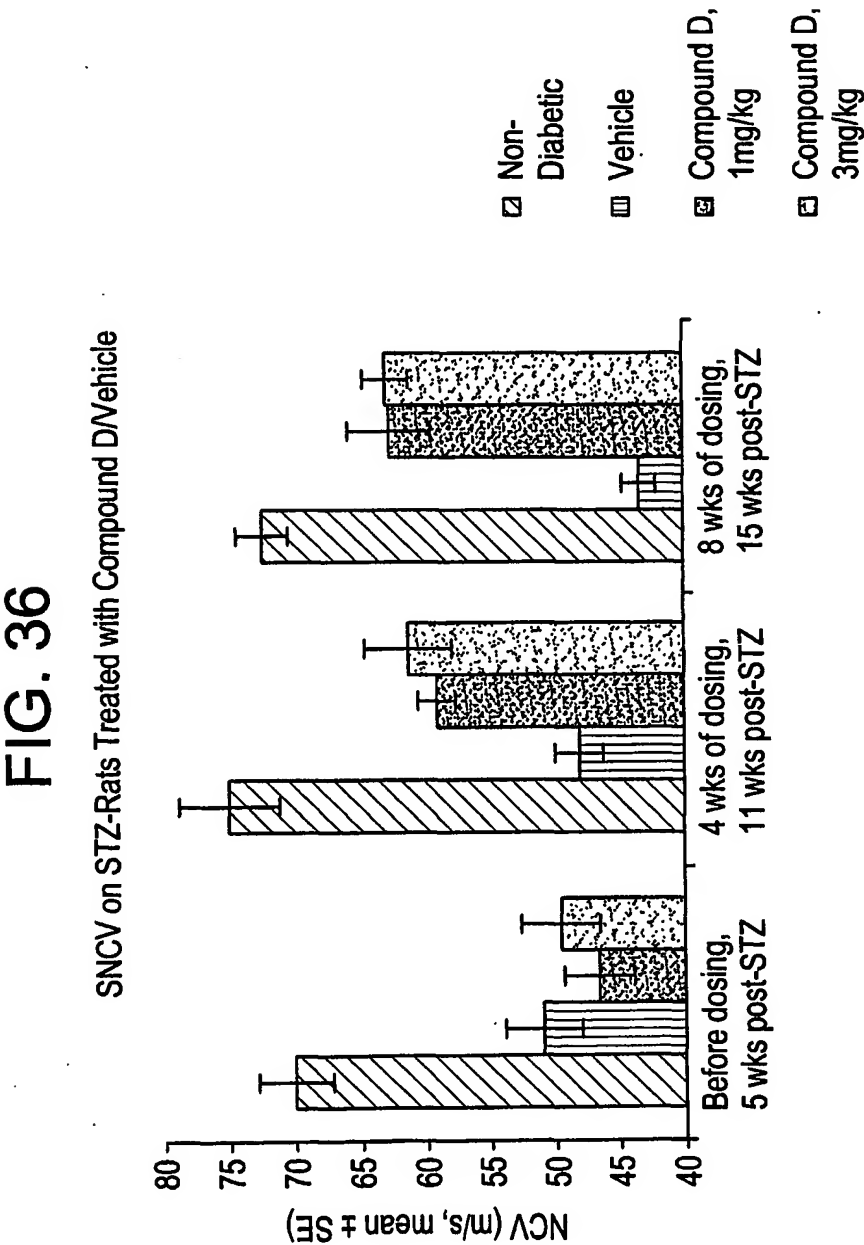
35/45



WO 02/057222

PCT/US02/01205

36/45

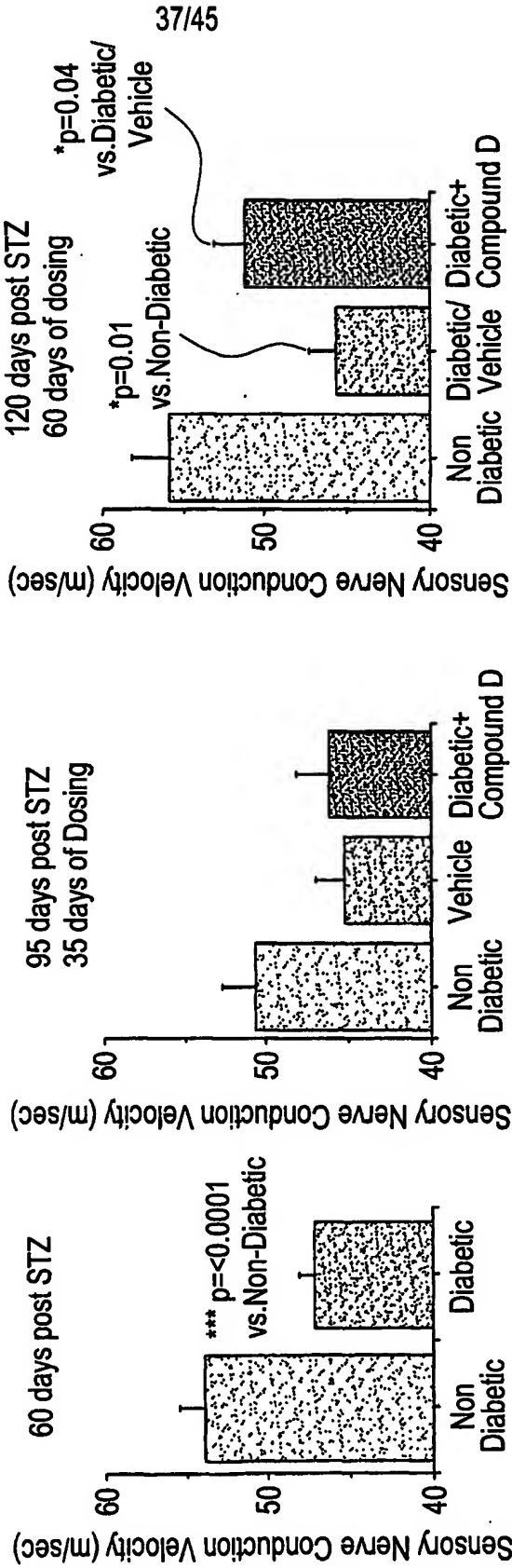


WO 02/057222

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FIG. 37

Compound D Reverses Sensory Nerve Conduction Velocity Deficit in Established Diabetes

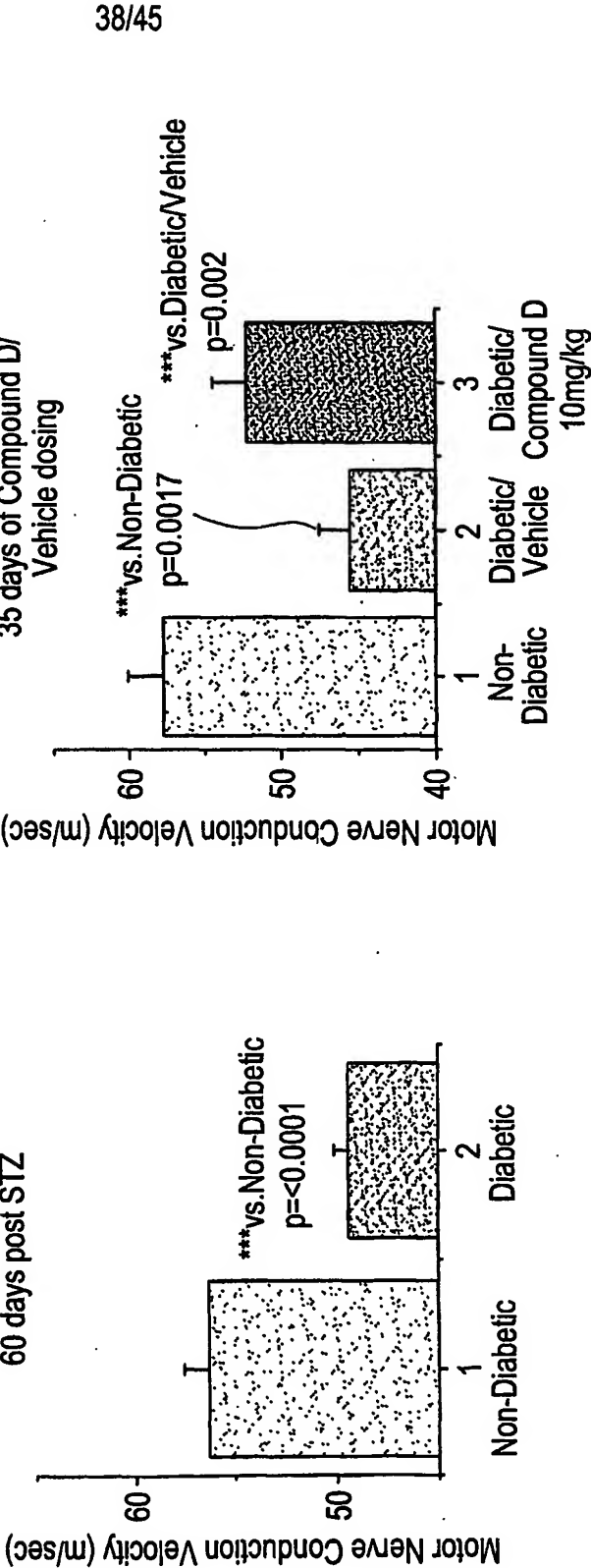


WO 02/057222

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FIG. 38

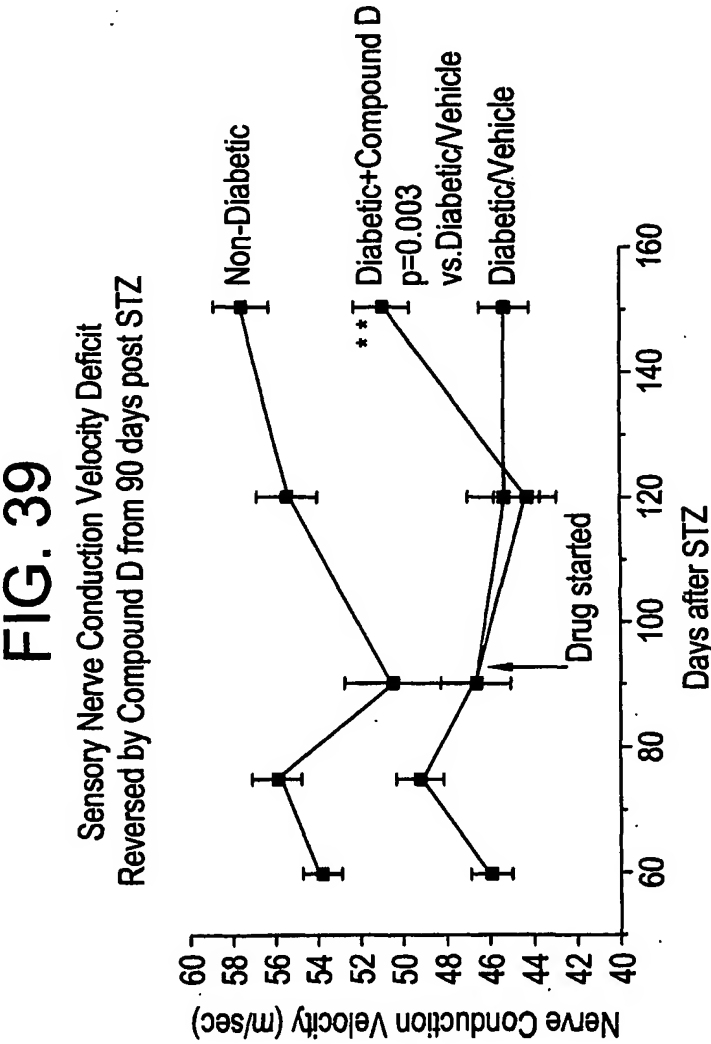
Compound D Reverses Motor Nerve Conduction Velocity Deficit in Established Diabetes



WO 02/057222

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39/45

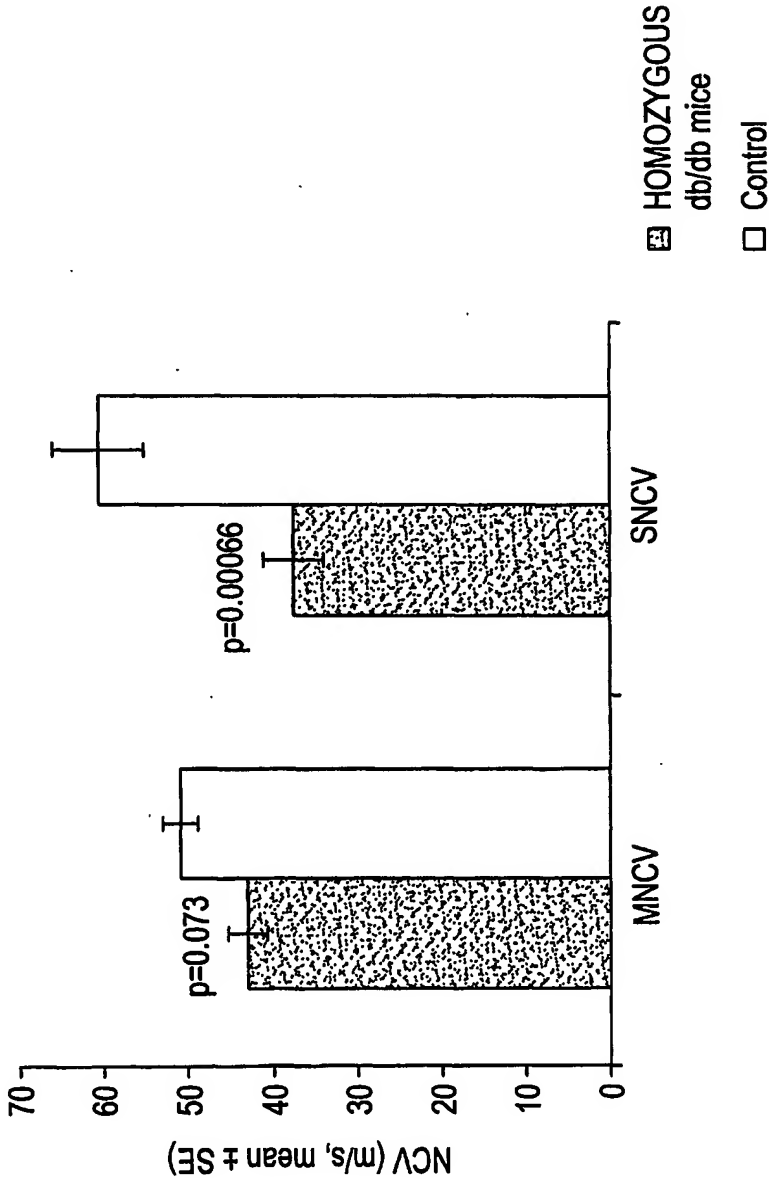


WO 02/057222

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40/45

FIG. 40
NCV in db/db Genetic Mouse Model of Diabetes
4 months of diabetes (pre-drug treatment)

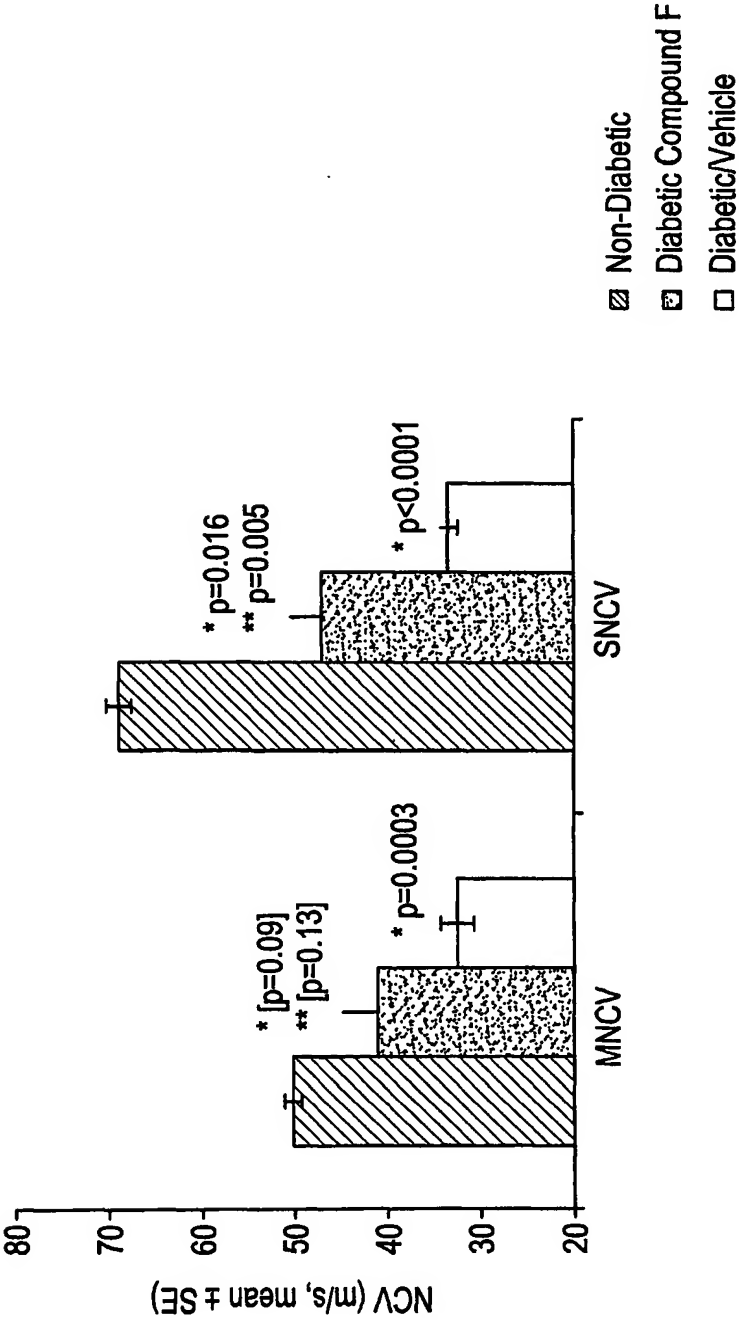


WO 02/057222

PCT/US02/01205

41/45

FIG. 41
NCVs in db/db mice
treated with Compound F (1mg/kg)/ Vehicle

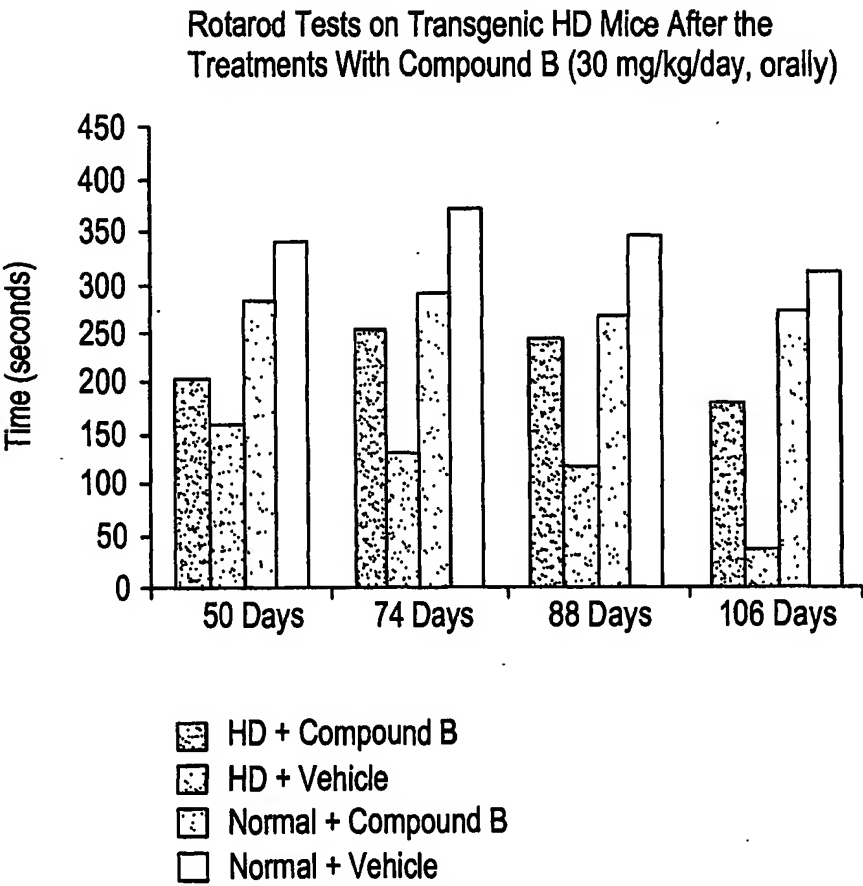


WO 02/057222

PCT/US02/01205

42/45

FIG.42

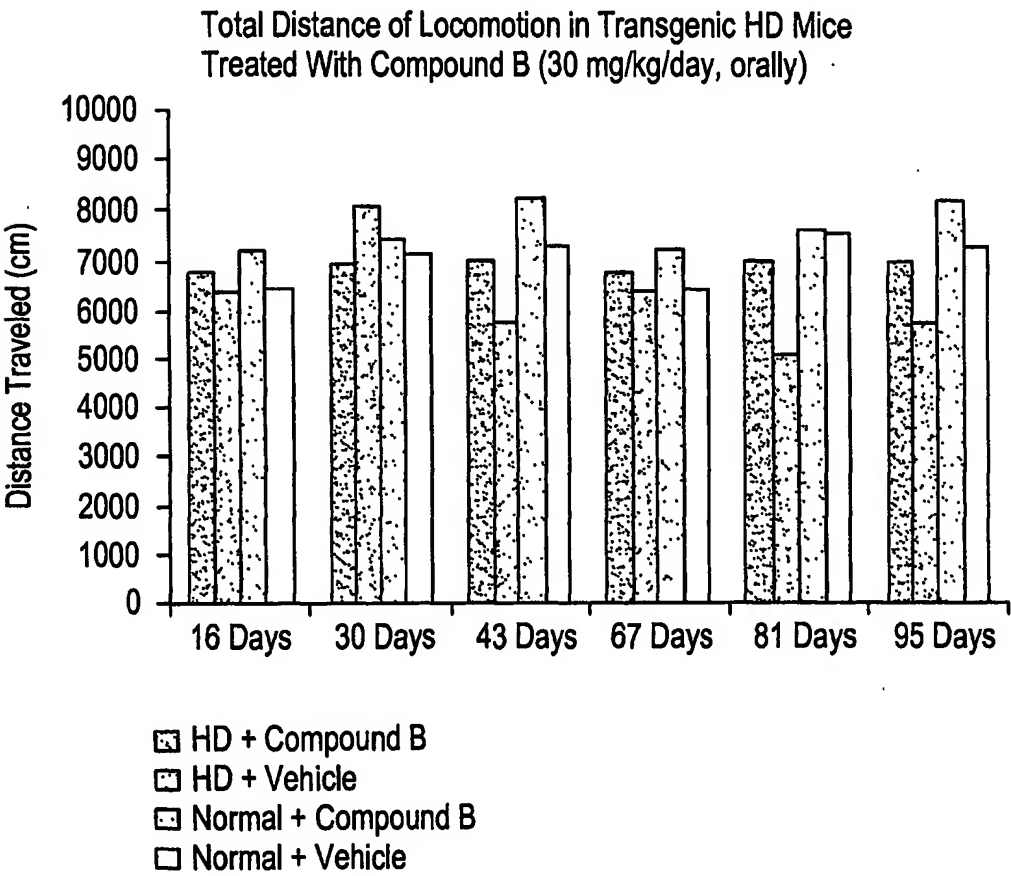


WO 02/057222

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43/45

FIG. 43

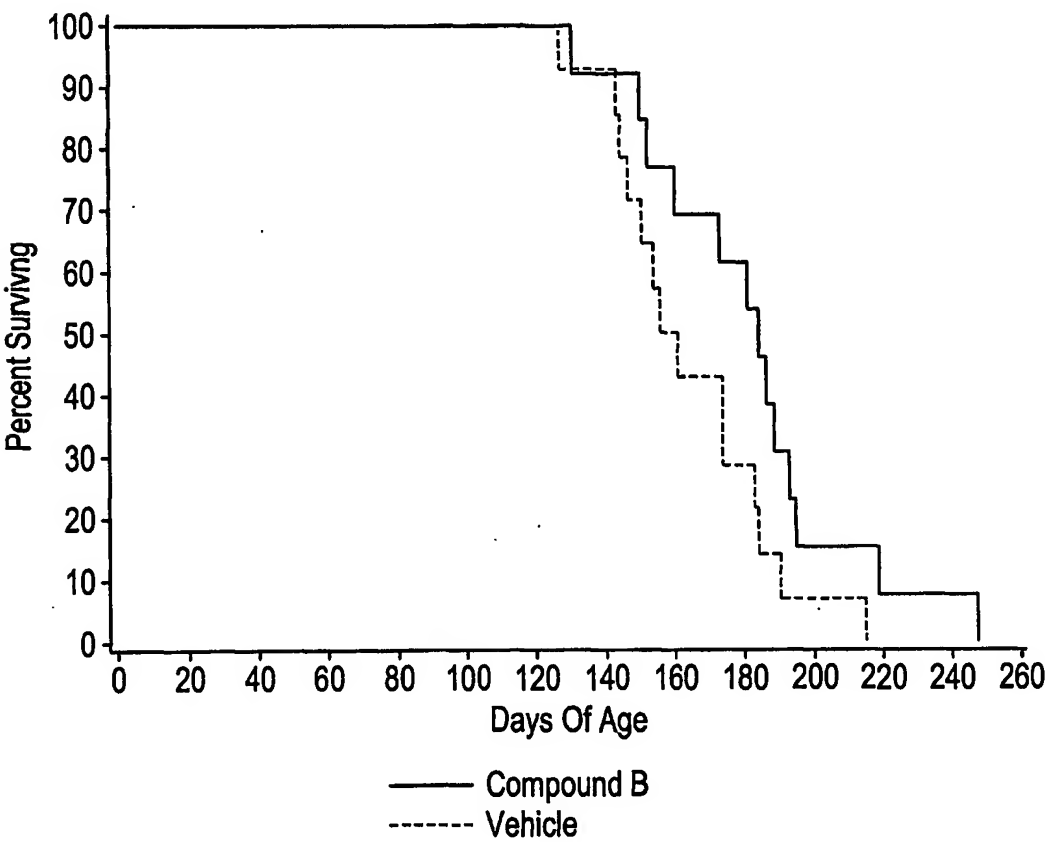


WO 02/057222

PCT/US02/01205

44/45

FIG. 44



WO 02/057222

PCT/US02/01205

45/45

FIG. 45

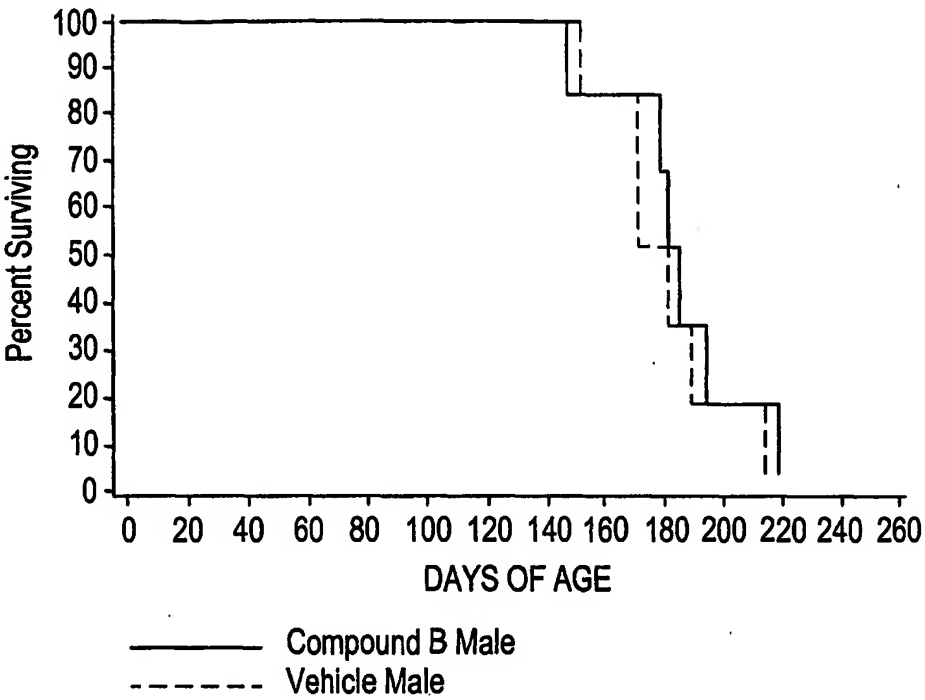
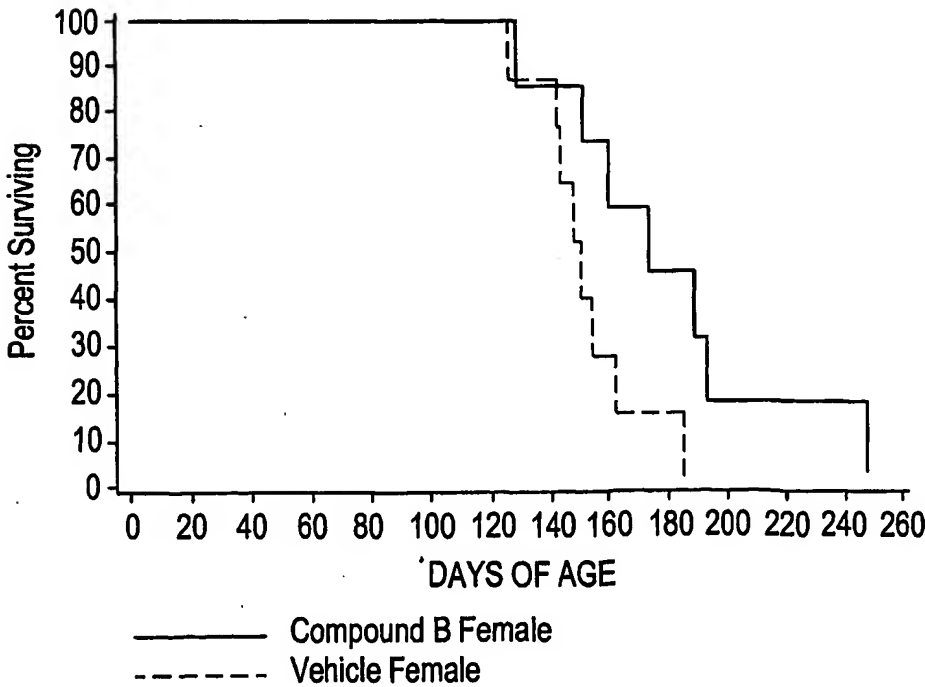


FIG. 46



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